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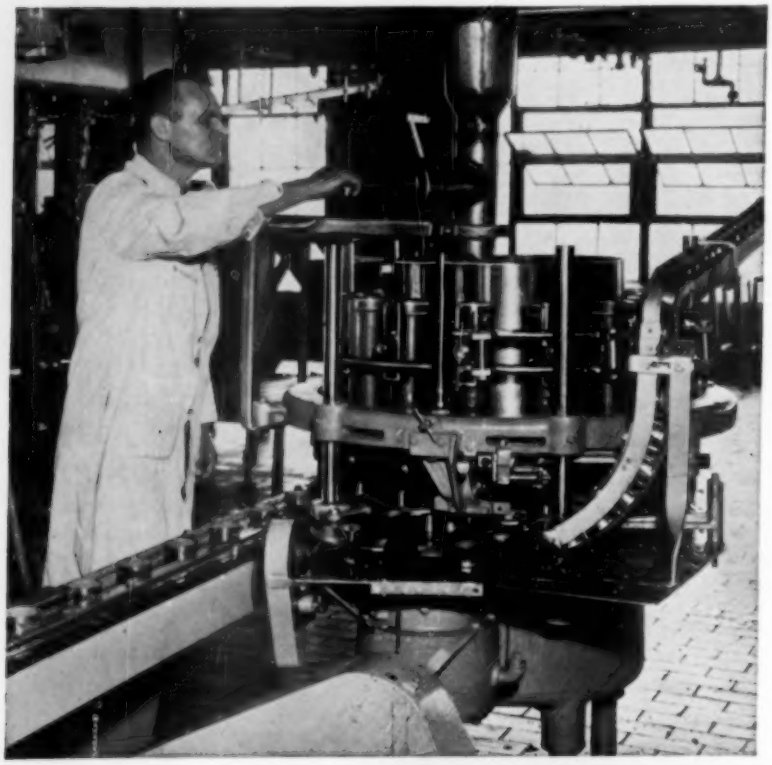

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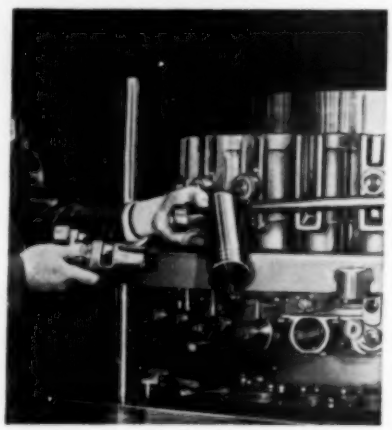

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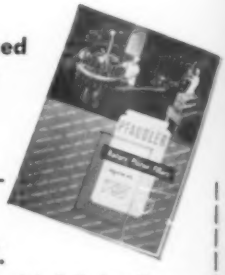

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The Transmission of Organic Vapors Through Packaging Materials[a]

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(Manuscript received May 12, 1951)

A procedure for measuring the rate of transmission of organic vapor through various packaging materials is described. The effects of relative humidity upon the transmission rate and of coating certain packaging materials with wax are discussed.

There are a number of factors which always require consideration when choosing the correct package for a given product. High on the list of these factors, along with such things as strength and grease resistance, is the ability of the package to resist the transfer of fixed gases such as oxygen, nitrogen and carbon dioxide, of water vapor, and of different odors. This is especially true in the food packaging field where, because of the great variety of entirely different materials, it is essential that the package be tailored to the product. Some products require a high degree of protection against moisture pick-up or loss while others are relatively unaffected by atmospheric conditions. Some require extra strength in the package; others, because they contain free oil, require a grease-resistant barrier.

In the same way there are a number of food products which are extremely susceptible to contamination by foreign odors and which suffer serious flavor changes in the presence of these odors. Commodities such as shortening, butter, and other fatty materials, as well as delicately flavored products such as tea, fall in this category. Other products whose flavor depends in part on volatile aromatic materials can lose sales appeal by diffusion of the flavor outward through the package.

Another class of products represented by dry cereals presents a somewhat different problem with regard to odor transfer. In order that cereal flakes retain their crispness, it is essential that the moisture content be maintained at a low level which, in turn, means that a good water vapor barrier must be used. Under these very dry conditions the cereals build up rancid odors which, unless they are vented, reduce the shelf life of the package. In this case, the ideal package would prevent the ingress of water vapor while permittng the rancid odors to escape.

While the methods of testing for water vapor transmission of packaging materials have been established and successfully used for a number of years, no corresponding simple method for measuring organic vapor transmission has been developed. There are a number of reasons for this. First of all, water vapor presents a much more serious problem than organic vapor and, accordingly, warrants more attention. Second, water is a single substance while an odor can be any one of a large number of organic materials. Third, the vapor pressure of water is high when compared with that of other materials and, fourth, it is efficiently absorbed by a large number of desiccants such as calcium chloride.

A number of different test methods have been proposed for measuring the rate at which odors pass through materials. Basically these methods can be divided into two main groups, subjective or organoleptic tests, and objective or instrumental tests. Each type has its inherent advantages and disadvantages. The organoleptic tests use relatively simple equipment and give the results in a short time. However, for the results to be reliable, these tests require the presence of several trained judges. Also, since they rely upon the senses of taste and smell, they are subject to human error and fatigue.

The instrumental test methods are superior to the organoleptic methods in that they eliminate personal judgment and give numerical results which can be duplicated. However, the instrumental tests have required cumbersome apparatus, trained operators, and special techniques.

Both organoleptic and instrumental tests suffer one other disadvantage. As has been mentioned, unlike water vapor, an odor can be any one of a number of compounds. This means that in establishing a test either one of two courses can be followed. The particular odor in question can be isolated and used in tests comparing various packaging materials or one odor can be selected and used as being representative. The former method is considerably more accurate since it gives the exact information desired. However, the results obtained in the second method are of a more general nature and capable of wider use, providing the limitations on the method are realized.

EXPERIMENTAL METHODS

The present test is an instrumental method. It uses simple, easily constructed cells and does not require any greatly specialized knowledge on the part of the operator.

The actual test cell is illustrated in Figure 1. It consists of two 125-mm. crystallizing dishes with one dish inverted on top of the other. A glass hook mounted in the center of the top dish has a small Petri dish hanging from it. The bottom half of the

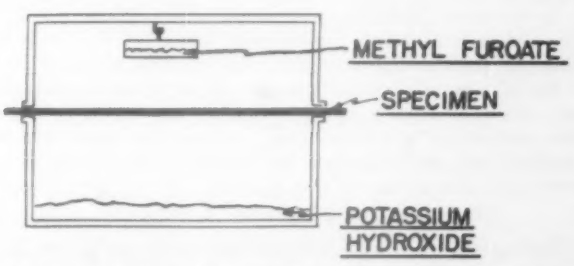

FIGURE 1. Schematic illustration of the test cell. The methyl furoate is in a Petri dish hanging on a glass hook.

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 19, 1951.

cell is plain. The rims on both dishes are ground flat to insure a reasonably tight seal against the sample.

When assembled for testing, the small Petri dish is half filled with a volatile organic liquid, methyl furoate. A fairly strong solution of potassium hydroxide is placed in the bottom dish and the specimen to be tested is mounted between the two dishes.

During storage, the methyl furoate volatilizes to fill the space in the upper half of the cell. The vapor then diffuses through the test specimen and is picked up in the potassium hydroxide solution. The essential chemical reaction in the test is as follows: Methyl furoate, in the presence of potassium hydroxide, reacts with water to form furoic acid and methyl alcohol.

At the completion of the test period the amount of furoic acid in the potassium hydroxide solution is measured by a spectrophotometer. The results are expressed as the grams of methyl furoate that would be transmitted by one square meter of test specimen in a 24-hour period.

Furoic acid, which is the substance actually measured in the spectrophotometer, has a high, sharp peak in its absorption spectrum at a wavelength of 245 mμ. The height of the peak, which is measured as the optical density of the solution, varies directly with the concentration of the furoic acid. Figure 2

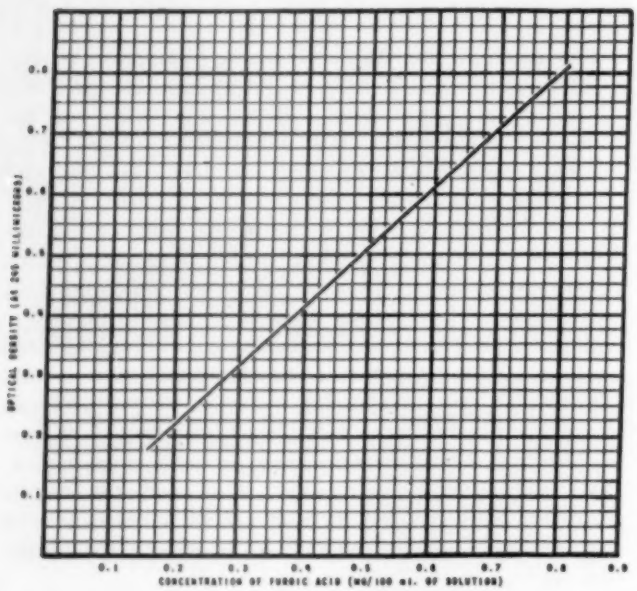

FIGURE 2. Calibration curve for the spectrophotometric determination of furoic acid in a 1*N* potassium hydroxide solution.

shows the calibration curve that was obtained when density readings were made on potassium hydroxide solutions containing various known quantities of furoic acid. The concentration of furoic acid in any unknown solution can be obtained from the optical density of the solution and the calibration curve.

Since the results are reported as grams of furoic acid per square meter per 24 hours, the concentration is divided by the number of days that the test ran and is multiplied by a factor to convert from the actual area of the test specimen (which is about 120 sq. cm.) to the square meter basis.

Methyl furoate was chosen as the odorous material for a number of reasons. It is sufficiently volatile, it can be stabilized, it is representative of a number of odors, such as oil of wintergreen, and it can be measured on a spectrophotometer which is a sensitive and accurate means for measuring small quantities of materials.

RESULTS

During the time the method has been under development, a number of tests have been run on some of the more common packaging materials. The average organic vapor transmission rates obtained in these tests are shown in Table 1. Some of the results are the averages of over 30 individual readings, while others are the average of only 2 or 3 tests. More tests were run on 2½ mil polyethylene and on 450-PT cellophane than on any of the other materials, principally because these two sheets gave uniform results and could be used as controls when investigating some of the variables that had to be eliminated during the development work.

TABLE 1

Organic vapor transmission rates of various packaging materials

Material	Grams furoic acid/sq. m./ 24 hrs.	Mean deviation	Mean deviation	Number of tests
			%	
Waxed full glassine	0.054	0.014	27	6
Plain full glassine	1.48	0.26	17	17
Plain cereal glassine	2.27	0.27	12	20
Waxed sulfite	0.485	0.099	20	21
Plain sulfite	11.9	0.50	4.0	3
450 PT cellophane	8.42	0.29	3.5	27
Polyethylene (0.0010 inch)	6.77	0.20	3.0	3
Polyethylene (0.0025 inch)	4.98	0.27	5.3	38
Polyethylene (0.0040 inch)	4.54	0.19	4.1	3
Polyethylene (0.0075 inch)	3.81	0.06	1.5	3
Saran 517.4 (0.0005 inch)	1.47	0.23	15.7	11
Saran 517.4 (0.0010 inch)	0.925	0.11	12.2	2
Saran 517.4 (0.0015 inch)	0.663	0.048	7.2	2

The second column of figures in Table 1 shows the average deviation of the results from the mean and the third column expresses these variations as percentages. These results indicate that some materials, particularly sulfite and glassine, have a large scatter in their transmission rates. Other materials such as polyethylene and cellophane had a variation of only ±5%.

An interesting feature of the results is the wide range of transmission rates that is covered. Where most other gas-transmission tests will give accurate readings within relatively narrow limits, this test has no absolute lower limit and has an upper limit of 14.0 g./sq. m./24 hrs.

The organic vapor transmission rates presented in the first column of results in Table 1 show some interesting relations between materials. It has been known that when a sheet of paper is coated with wax, the rate at which odors pass through the sheet is reduced. It has not been known exactly how much the transmission rate is reduced. A comparison of the results obtained on plain glassine and plain sulfite with the results obtained on the waxed sheets shows that when 5 lbs. of wax per ream are placed on the sheets, the organic vapor transmission rate is reduced to one-fortieth of the value obtained on the plain sheets. Tests have not yet been run on sheets coated with less than 5 lbs. of wax nor have very many different types of coatings been tested. It is expected that when data of this type are available, it will be possible to combine the results with the results from other tests, especially water-vapor-transmission studies, to obtain the best material for a given packaging application. In the case of dry cereals, mentioned earlier, this means that it will be possible to select the sheet which presents the best compromise between a high organic vapor transmission rate and low water vapor transmission rate.

Figure 3 is an example of the type of data that can be developed from tests of this nature. Both organic and water vapor transmission studies were run on 1 mil, 2½ mil, and 4 mil polyethylene. The results show that the 1 mil sheet transmitted water vapor almost twice as fast as organic vapor, while the 4 mil sheet permitted both to pass at the same rate. This is the reverse of what would be needed for the dry cereals.

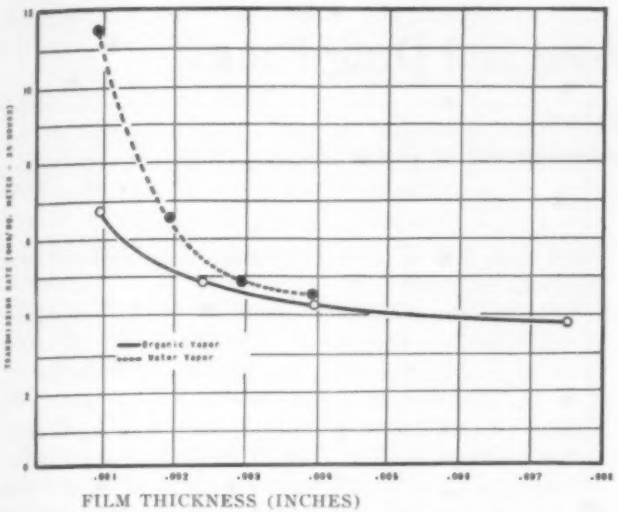

FIGURE 3. Water vapor and organic vapor transmission rates of polyethylene film.

In conducting tests on new packaging materials careful observations should be made of the sheets at the end of the test because it has been found that the methyl furoate apparently is soluble in some coating solutions. Results obtained in such tests should be discounted since for the particular material in question, methyl furoate is not a representative odor. To date only one such material has been found, MSAT-83 cellophane.

Effect of relative humidity on transmission. A surprising feature of the results in Table 1 is the high transmission rate that is shown for 450-PT cellophane. Ordinarily, cellophane is thought of as a fairly good odor barrier and, for certain products, it is. When tests were run in an effort to explain the apparently erroneous results obtained on cellophane, it was found that the transmission rates of cellophane and other cellulosic sheet materials, such as sulfite and glassine, are extremely dependent upon the relative humidity at which the tests are run. Table 2 presents the results of organic vapor transmission tests that were conducted with the atmosphere held at 34% relative humidity and other tests that were run on the same materials at 84% relative humidity. Cellophane, glassine, and sulfite all show a higher transmission rate at the higher humidities than they do at the low humidities. Poylethylene, on the other hand, shows very little change.

TABLE 2

Effect of relative humidity (R. H.) on the transmission rate of packaging materials

Material	Organic vapor transmission rate (g./sq. m./24 hrs.)	
	at 84% R. H.	at 34% R. H.
Waxed full glassine	0.054	0.0030
Plain full glassine	1.48	0.042
Waxed sulfite	0.485	0.265
Plain sulfite	11.9	8.08
450 PT cellophane	8.42	1.03
Polyethylene (0.0025 inch)	4.98	4.76

Since the relative humidity in the test is dependent on the concentration of the potassium hydroxide in the bottom half of the cell, it is a very simple matter to obtain any desired relative humidity by adjusting the concentration of the potassium hydroxide.

In practical applications, then, it is necessary to consider not only the organic vapor transmission rate of the sheet, but also the moisture content and other characteristics of the product that is to be packaged. If, for example, a moist product such as shredded coconut or fresh vegetables is being protected against odor pick-up, an entirely different material may be required from that which would be used on a dry product such as tea.

Correlation with organoleptic tests. To correlate the organic vapor transmission rates with sniff tests, five bell jars were assembled with oil of wintergreen in the bottom and with different types of packaging materials between the body of the jars and lids. Stoppers in the lids were removed periodically and the air in the top section of the jars was sniffed in an effort to detect the oil of wintergreen. Table 3 gives the times at which the odor was first detected, as well as the organic vapor transmission rates for these materials. The agreement between the two columns of figures, although not perfect, is fairly good.

TABLE 3

Correlation between sniff tests and organic vapor transmission tests for various packaging materials

Test materials	Oil of wintergreen first detected	Organic vapor transmission rate of methyl furoate at 34% R. H.
	minutes	*g. furoic acid/sq. m./24 hrs.*
Plain sulfite	3	8.08
Polyethylene (0.0025 inch)	20	4.76
450 PT cellophane	65	1.03
Plain glassine	195	0.042
Waxed glassine	1440	0.0030

A number of other factors, such as temperature, undoubtedly will influence the rate of transfer of organic vapors through packaging materials, but these factors have not been studied as yet.

A series of tests are in progress now to determine how well methyl furoate represents various classes of odorous materials. The transmission rates of benzaldehyde and of acetic acid through several of the more common materials are being established to determine whether methyl furoate can be used as representative of the type odors which benzaldehyde and acetic acid represent.

SUMMARY

A factor which very often determines the suitability of a packaging material for a given application is the resistance which the sheet offers to organic vapors. The present test procedure provides a simple, objective means for determining the organic vapor transmission rate of packaging materials.

A split cell technique is used with a small dish of methyl furoate suspended in the top half and a potassium hydroxide solution in the bottom. The test specimen is mounted between the two. The methyl furoate, after passing through the sheet, is converted to non-volatile potassium furoate by the potassium hydroxide. The quantity of potassium furoate is measured spectrophotometrically.

Studies made using this procedure have shown that when a wax coating of 5 lbs. per ream is applied on sulfite and glassine, the organic vapor transmission rate is reduced to one-fortieth that of the uncoated sheet. It has also been found that the moisture content of the sheet has a great influence on the transmission rate. Some sheets transmit organic vapors ten times as fast at high relative humidities as at low humidities.

Control of Sanitation in Food and Drug Plants*

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(Manuscript received May 28, 1951)

The responsibility of the food technologist in the control of sanitation in food and drug plants is emphasized. Sources of contamination and means of control are discussed.

Some time ago I read a Food and Drug Inspector's report in connection with a visit to a large brewery. The inspector wished to explore the conveyor system that carried the corn grits from the railroad siding to the storage bins located on the top floor. To inspect the interior of the conveyor, he had to scrape off six or seven layers of paint from the cleaning plate and get help to remove some of the bolts with a cold chisel. Inside the conveyor he found a mass of webbing and debris in which a variety of grain insects were multiplying by the thousands.

This example, I think, is symptomatic of an attitude still widely prevalent in industry, that considers "sanitation" as something abstract or a thing apart—something like religion only on Sunday—instead of a part of the daily routine of conduct. Some members of the industry overlook the application of sanitation and the need for sanitary practices in everyday operations until suddenly a Food and Drug Inspector visits their plant, and, the next thing they know, there is a seizure or a citation and they are in trouble. Then they hire an exterminator or a sanitation expert, who is supposed to get them out of the mess.

In considering the problem of plant sanitation, it is important to remember that the regulatory concepts in the Food, Drug, and Cosmetic Act of 1938 are much broader and more basic than were those in the Food and Drugs Act of 1906. Under the old Act, regulatory action could be developed only on the basis of objective findings in the product itself, capable of demonstration to the point of proof in court that the article was filthy. Under the current Act of 1938, the objective basis for action has been broadened to include the generalized category, "or if it is otherwise unfit for food." More important, however, is the broadening of the base which adds an entirely new group of violative acts, namely, "if it has been prepared, packed, or held under insanitary conditions whereby it may have become contaminated with filth or whereby it may have been rendered injurious to health."

Since the possibilities of violation from the standpoint of sanitation are inseparably bound up with all of the phases of food production and marketing, from the design and construction of the plant and equipment to the control of uniformity of output, innovations in packaging, and reduction in costs in placing of the product in the consumers' hands, they cannot be divorced from the responsibilities of the food technologists, who, all along the line, must come to grips with the various basic applications of sanitary control.

A great deal of progress has been made in the sanitary quality of the nation's food supply in the thirteen years since the Food, Drug, and Cosmetic Act became law. This improvement could not have been achieved through law enforcement alone. Credit for much of it is due to the leaders in the affected industries, who have recognized and coped with sanitation as a problem of first importance. Much credit belongs also to industry educational programs and self-policing activities and to groups of experts sponsored by the food industries, who have contributed a great deal by way of improvement. However, there still remains much to be done.

Let us consider, for the sake of illustration, a "synthetic" hypothetical case. By "synthetic" I mean that not all of the factors were present simultaneously in the same plant. The actual conditions, however, were noted separately or in various combinations in several plants, and thus are true to fact.

The inspector's report of visit to this hypothetical factory devoted considerable space and emphasis to a description of the management's efforts to put out a really superior article. Stainless steel tables and equipment had been installed at great expense, and a crew was assigned to keep them spotless and polished. The latest devices and gadgets had been introduced to control processing time and temperature automatically, and the entire system had been devised to make it foolproof and to eliminate entirely the possibility of a lapse through human failure. A series of extensive experiments and expensive investigations were underway to test the shelf-life of the product. New package designs with ultra-modern color motifs worked into the labels and wrappers had just been introduced, and polls were

* Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951.

underway to test consumer acceptance. All of these special features were being directed by the food technologist, who had received excellent basic training and had had specialized college courses and extensive experience in the field of food technology.

When samples of finished products out of this plant were collected from interstate shipments and examined in our laboratory by the usual microanalytical methods, they were found to contain numerous insects and insect fragments and even rodent hairs and portions of rodent excreta pellets. The answer to their presence was found in the second half of the inspector's factory inspection report. Here he described how the openings in the walls and in the basement floor for the passage of steam and water pipes had not been sealed tightly. He told how rodents had ready access to the plant from the trash-littered vacant lot next door; how the slick, greasy trail of the rodent runway was confirmed by rodent droppings in relatively inaccessible places behind steam pipes running along the stainless steel tables on which enrobed candy pieces were held overnight. He found that some of the new, spotless equipment was so constructed that portions of unfinished food fell into covered recesses and spaces not readily observed or easily accessible. This accumulation of spilled material provided a breeding place for insects that found their way through crevices and cracks into the food production line and frequently perished in the transition. In brief, these objectionable conditions in a plant that superficially looked cleaner than average proved the undoing of the firm in spite of brilliant technological innovations.

Food technology applies science and engineering processes to the production, processing, packaging, distribution, and utilization of foods. It is intended to eliminate "rule of thumb" methods and to supplant them with processes based on scientific facts and principles. In the study of your problem, let me ask you, "Do you always give full weight to the sanitary aspects, so that what you recommend will incorporate the latest approved sanitary improvements?" This concept must start with the very designing and construction of a plant itself. In the long run, it is easier to block out rodents than later to try to drive them out. It is easier to set equipment in such position that cleaning around it can be done effectively than later to spray with insecticides and poke around trying to eliminate insect harborages. It is easier to design and build equipment in which there can be no accumulation of mixing materials to serve as breeding places for infestation than it is to try to eliminate infestation that has gained a foothold. It is easier to design package wrapping that will prevent insect entry than to have to recall infested stocks later from retailers' shelves.

Food technologists are in the habit of giving thorough consideration to bacteriological problems of sterilization, to the problem of cutting down the processing and holding time required for the food to travel from the state of raw material to the finished package stage. They explore the possibilities of development of mold, yeasts, and spores as a result of holding overnight on tables or conveyors or in the dryers or in other equipment. Frequently they do not give equal consideration to the possibilities of rodent or insect depradations during such holding periods. Some of our inspectors have gone, for example, into a confectionery plant where candy pieces were left overnight in cooling tunnels and where mouse pellets were found on the candy and on the belt. In one instance that comes to mind, a pan was hung under the enrober belt to catch the chocolate drippings, which were then returned to the kettle. The suspended pan apparently had never been cleaned thoroughly because, upon removal by the inspector, it was found to contain a considerable accumulation of enrobed rodent pellets.

The Food, Drug, and Cosmetic Act now has underway an investigation of the rodent and insect infestation occurring in wheat and flour. This provides a good example of a technological problem, the solution of which will contribute to the general improvement of a large and important proportion of the nation's food supply. Like many natural agricultural products, wheat is subject to insect and rodent attack from the time of production on the farm until it is converted into flour. With the cooperation of the flour-milling industry, a program of study was undertaken over a year ago, the broad purpose of which is to determine the level of internal and other insect and rodent infestation in wheat and to ascertain the degree to which such infestation can be removed by good milling practices. A similar program is underway in the cornmeal industry. The results of these investigations will not only serve as a guide to the Food and Drug Administration in future regulatory operations, but will be of inestimable value to educational and Government institutions interested in research and improvement in grain and flour, and to the grain, flour, and meal industries in planning their own self-improvement programs.

The Food, Drug, and Cosmetic Act does not demand 100% perfection in food products. In the case of many natural, agricultural products that would be impossible. It does, however, demand that the manufacturer employ recognized good manufacturing practices. In that broad term are included a number of considerations. The manufacturer must, for example, use reasonable precautions and give proper attention to the sanitary quality of his raw materials. He must employ up-to-date sanitary practices in his plant. He must keep his machinery clean and must not use machinery that is incapable of being cleaned. If accidental contamination occurs, he must see to it that effective elimination procedures are instituted at once. He must so handle and store his finished food products that the final user will receive them in clean, sanitary condition.

To summarize, sanitation in a food plant is primarily a problem of prevention, that is, building and blocking out rodents, vermin, and insects; controlling the raw materials coming into the plant; supervising human behavior during processing and packaging; designing and maintaining machinery, conveyors, and utensils which will not themselves become a source of contamination; and packaging, storing, and distributing the finished articles of food so that they will reach the ultimate consumer without deterioration or contamination.

In the measure that these requirements touch the food technologist, to that extent must he meet their challenge.

Gelation and Clarification in Concentrated Citrus Juices I. Introduction and Present Status[a,b]

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(Manuscript received July 10, 1951)

Gelation and clarification in citrus concentrate are the result of enzymic changes and many factors determine the rate at which these changes take place. Basic factors of importance are the pectin concentration, the pH, the bivalent ion concentration, and enzyme activity in the concentrate. Practical factors involved are fruit variety, quantity and type of pulp used, degree of concentration, and storage temperature.

The possible use of variations in processing procedures, heat inactivation of enzymes, chelating agents, and enzymic inhibitors as means for preventing gelation and clarification are presented.

Various problems have been encountered during the rapid expansion of the citrus concentrate industry in Florida from 226,000 gal. of frozen orange concentrate in 1945-46 to 21,600,000 gal. in 1949-50. Of major importance from a quality standpoint has been the occurrence of gelation and clarification in concentrated citrus juices. These changes result from the action of pectic enzymes on pectin present in the juices. Some research has been done relative to the pectic enzymes found in citrus juices *(4, 13, 14)* and the causes and prevention of clarification in canned citrus juices have been studied extensively *(6, 10, 11, 12, 17, 20, 22)*. Studies on the clarification of citrus concentrate were reported by Cotton, Roy, Brokaw, McDuff, and Schroeder *(5)* and more recently have been discussed by Stevens, Pritchett, and Baier *(21)*. Curl, Moore, Wiederhold, and Veldhuis *(7)* reported lumpiness and a loss of pectin in various citrus concentrates stored at various temperatures. Rouse *(19)* showed that in frozen citrus concentrate which had been thawed and stored at 40° F. (4.5° C.), gelation was caused by low-methoxyl pectin formed by the enzymic action of pectinesterase on the pectin present in these products. Owens, McCready, and Maclay *(16)*, Woodmansee and Baker *(23)*, Joseph, Kieser, and Bryant *(9)* and Hills, Mottern, Nutting, and Speiser *(8)* have reported on the gelation characteristics of various types of low-methoxyl pectins. An interesting review of the field of high-polymer pectins and their de-esterification has been presented by Baker *(3)*.

The purpose of this paper is to discuss briefly basic and practical factors involved in this problem of gelation and clarification of concentrated citrus juices and possible methods for prevention of these enzymic changes which affect the quality of these products.

BASIC FACTORS RELATED TO GELATION AND CLARIFICATION

Four basic factors related to gelation and clarification are pectin concentration, pectinesterase activity, pH, and bivalent ion concentration, especially calcium. The presence of pectin makes possible the desirable "cloud" low-methoxyl gels are formed following the enzymic demethylation of the pectin. The methoxyl content of the pectin and the pectinesterase activity found in some reconstituted frozen concentrated citrus juices, as reported by Rouse *(19)*, are shown in Table 1. The degree of citrus juices, and the enzymic breakdown of pectin causes clarification. Also, as previously pointed out,

TABLE 1

Low-methoxyl pectin gelation in citrus concentrates stored at 40° F. (4.5° C.) resulting from demethylation of pectin by pectinesterase

	Days storage					
	0	6	12	18	24	30
Duncan grapefruit, 38.1° Brix, pH 3.2						
Degree of gelation	None	Slight	Semi-gel	Solid gel	Solid gel	Solid gel
Calcium pectate, %	0.16	0.15	0.15	0.10	0.12	0.16
Methoxyl content of pectin, %	4.67	4.46	4.33	3.99	3.41	3.22
Hamlin orange, 43.4° Brix, pH 3.5						
Degree of gelation	None	Slight	.....	Slight	.....	Semi-gel
Calcium pectate, %	0.16	0.14	.....	0.13	.....	0.16
Methoxyl content of pectin, %	6.81	6.53	.....	6.11	.....	5.87
Valencia orange, 42.0° Brix, pH 3.7						
Degree of gelation	None	.....	None	None	.....	Slight
Calcium pectate, %	0.14	.....	.....	0.11	.....	0.09
Methoxyl content of pectin, %	6.53	.....	.....	5.31	.....	4.56

of gelation that is caused by further demethylation of the pectin when the concentrates were stored at 40° F. (4.5° C.) for one month is also shown in Table 1. Typical gelation in concentrated orange juice and concentrated grapefruit juice is shown in Figure 1.

Baker *(1)* reported that the optimum pH for jellied grape juice is 3.1, with an optimum range between 2.7 and 3.4. All fruit juices do not necessarily have the same optimum pH for low-methoxyl pectin gels, but the pH of most citrus juices will be within the pH range of 2.9 to 4.0. Therefore, the pH of citrus juices is often suitable for gel formation.

Calcium or other polyvalent ions are necessary for the gelation of low-methoxyl pectin. Baker and Goodwin *(2)* have established the optimum amounts of calcium at optimum pH for a number of pectinic acids (low-methoxyl pectins), with varying methoxyl contents necessary for the formation of low-methoxyl gels.

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 19, 1951.

[b] Cooperative research project of Florida Citrus Commission and Florida Citrus Experiment Station, Lake Alfred, Florida. Florida Agricultural Experiment Station Journal Series No. 8.

[c] Florida Citrus Experiment Station.

[d] Florida Citrus Commission.

FIGURE 1. Low methoxyl pectin gelation in Hamlin orange concentrate (left, semi-gel) and Duncan grapefruit concentrate (right, solid gel) after storage at 40° F. (4.5° C.) resulting from demethylation of pectin by pectinesterase.

These gels contained 40% added sugar, which is reasonably close to the total soluble solids in frozen citrus concentrate. They reported 0.003% as the optimum amount of calcium necessary for gelation using an enzyme-demethylated pectin with a methoxyl content of 5.52% at an optimum pH of 2.7. Roberts and Gaddum *(18)* found that calcium in citrus juices ranged from 0.008 to 0.016%. Thus, citrus juices contain more than the optimum amount of calcium necessary for the formation of enzyme-demethylated pectin gels.

PRACTICAL FACTORS RELATED TO GELATION AND CLARIFICATION

Factors of practical significance related to the problem of gelation and clarification are fruit variety, amount and type of pulp in the concentrate, degree of concentration, and temperature of storage. The degrees of gelation and clarification in concentrates made from Hamlin, Valencia, and Pineapple oranges, Dancy tangerines, and Marsh and Duncan grapefruit are shown in Table 2. The importance of fruit variety is readily

TABLE 2

Gelation and clarification in concentrated juices from six varieties of citrus fruit

Type	Variety	Degree of gelation after 1 month at 40° F. (4.5° C.)	Degree of clarification after 1 month at 10° F. (—12° C.)	° Brix (By refractometer at 28° C.)	pH
Orange	Hamlin	None	Definite	42.3	3.6
Orange	Pineapple	Semi-gel	None	42.1	3.7
Orange	Valencia	Very slight	None	42.2	3.6
Tangerine	Dancy	None	None	42.1	3.6
Grapefruit	Duncan	Solid gel	Extreme	42.1	3.1
Grapefruit	Marsh	Very slight	Definite	41.9	3.3

apparent; for example, the seedy varieties, Pineapple orange and Duncan grapefruit, are more susceptible to gelation than the less seedy varieties. Clarification takes place more rapidly than gelation and also in some instances, as with Marsh grapefruit, definite clarification occurs, whereas only slight gelation takes place.

Data presented in Table 3 indicate that the degrees of gelation and clarification in a citrus concentrate are dependent upon the total soluble solids present in the product. Maximum gelation and clarification were obtained at a soluble solids content of 30-40° Brix with less gelation and clarification at both lower and higher

TABLE 3

Gelation and clarification in Pineapple orange concentrate at different levels of concentration

° Brix (By refractometer at 28° C.)	Extent of concentration (approx.)	Degree of gelation of concentrate after 1 month at 40° F. (4.5° C.)	Degree of clarification of	
			Concentrate after 21 hr. at 80° F. (26.5° C.)	Reconstituted juice after 21 hr. at 80° F. (26.5° C.)
12.0	None	.....	.....	.....
23.2	2-fold	None	None	None
32.3	3-fold	Semi-gel	Extreme	None
41.4	4-fold	Semi-gel	Extreme	None
50.5	5-fold	Slight	Slight	None
64.3	7-fold	None	None	None

degrees of concentration. This relation between clarification and total soluble solids was previously reported by Cotton et al. *(5)*. Rouse *(19)* reported maximum pectinesterase activity in 41° Brix orange concentrate. Data in Table 3 also show that clarification occurs more rapidly in 30-50° Brix concentrate than in corresponding reconstituted juices.

Moore, Huggart, and Hill *(15)* reported that gelation and clarification may take place when frozen citrus concentrates are stored at 10° F. (—12.0° C.), 20° F. (—6.5° C.), 32° F. (0° C.), and 40° F. (4.5° C.). The degrees of gelation and of clarification that occurred when Pineapple and Valencia orange and Duncan grapefruit concentrates were stored at 10° F. (—12.0° C.) and 20° F. (—6.5° C.) for three months *(15)* are presented in Table 4. The rate of gelation and clarification increased with an increase in the storage temperature.

To determine whether the use of freeze-damaged fruit would result in increasing gelation and clarification in citrus concentrates, mature fruit was picked, frozen, and then processed after thawing. The concentrate made from frozen fruit showed a greater degree of gelation than concentrate made from the control lots of unfrozen fruit (Table 5).

PREVENTION OF GELATION AND CLARIFICATION

Possible methods for the reduction or prevention of gelation and clarification in concentrated citrus juices are elimination of excessive amounts of pectin and enzyme activity through modification and control of processing procedures, storage of frozen citrus concentrates at temperatures of 0° F. (—18.0° C.) or lower at all times, enzyme inactivation by heat treatment, addition of chelating agents, or addition of enzyme-inhibiting substances.

Since seedy varieties of fruit are more susceptible to gelation, certain precautions may be taken in processing them to minimize gel formation. For example, the removal of seeds and rag from the freshly extracted juice as soon as possible after extraction and prior to the entrance of the juice into the juice finisher will decrease the degree of gelation that may occur, since the pectic substances in the rag and seeds are contributing factors to gelation. Also, since pectic enzymes and pectin are associated with the insoluble cellular material in the pulpy cut-back juice, the elimination of excessive amounts of pulp and the use of specific types of pulp in the pulpy cut-back juice will reduce the degree of gelation and clarification. The exact quantities of the dif-

TABLE 4

Effect of storage temperature on gelation and clarification in concentrated citrus juices

	Condition of concentrate after storage for 3 months					
	Pineapple orange		Valencia orange		Duncan grapefruit	
	10° F. (—12.0° C.)	20° F. (—6.5° C.)	10° F. (—12.0° C.)	20° F. (—6.5° C.)	10° F. (—12.0° C.)	20° F. (—6.5° C.)
Gelation	Very slight	Semi-gel	Very slight	Slight	Very slight	Semi-gel
Clarification	None	Definite	None	Definite	Extreme	Extreme

TABLE 5

Effect of use of frozen fruit * on gelation and clarification in concentrated citrus juices

	Pineapple orange		Valencia orange		Duncan grapefruit	
	Not frozen	Frozen	Not frozen	Frozen	Not frozen	Frozen
Gelation after 24 hr. at 80° F. (26.5° C.)	None	Semi-gel	None	Very slight	None	Solid gel
Clarification after 7 hr. at 80° F. (26.5° C.)	None	Slight	None	Definite	Definite	None

* Harvested fruit in field boxes was frozen by storage at —8° F. (—22.0° C.) for 18 hours, then stored at room temperature for 24 hours before processing.

ferent types of pulp that may be used without causing difficulty have not yet been determined.

Since enzymic changes do not take place rapidly at low temperatures, gelation and clarification in frozen citrus concentrate may be prevented if processors, distributors and consumers always store these products at the recommended temperature of 0° F. (—18.0° C.) or lower.

The prevention of gelation and clarification in citrus concentrates may be brought about by the application of heat to inactivate the enzymes causing these changes, provided that the temperature and holding time used is sufficient to completely inactivate the enzymes. It has not yet been demonstrated that heat inactivation of enzymes can be accomplished without definitely affecting the flavor and thereby lowering the quality of the product. Research is being carried on to determine the best possible methods for the production of concentrated citrus juices in which the enzymes have been inactivated by heat. Data given in Table 6 show results obtained

TABLE 6

Relation of heat treatment of Pineapple orange juice before concentration to 42° Brix on gelation, clarification, and retention of pectinesterase activity

Thermal treatment		Degree of gelation after 24 hours at 80° F. (26.5° C.)	Degree of clarification after 24 hours at 80° F. (26.5° C.)	Pectinesterase activity (Retention, %)
° F.[1]	° C.			
Control	(not heated)	Solid gel	Extreme	100
125	51.5	Solid gel	Extreme	100
135	57.0	Solid gel	Extreme	100
145	63.0	Semi-gel	Extreme	96
155	68.5	Slight	Slight	66
165	74.0	None	None	22
175	79.5	None	None	4
185	85.0	None	Slight [2]	2
195	90.5	None	None	0

[1] Juice heated to noted temperature in 3 seconds, and immediately flashed into evaporator.

[2] Questionable.

relative to the gelation and clarification of Pineapple orange juice concentrated to 42° Brix (no cut-back); prior to concentration the pulpy juice was heated to temperatures ranging from 125° to 195° F. (51.5° to 90.5° C.).

The addition of chemical substances to citrus juices is not desirable for various reasons. However, preliminary investigations have been made using various chelating agents, such as Versene, to determine whether they would prevent gelation and clarification. Also, the use of some enzyme inhibitors, such as the surface active alkyl aryl sulfonates, was investigated. None of these additives was found to prevent gelation and clarification unless excessive quantities were used.

SUMMARY

1. Gelation and clarification of concentrated citrus juices caused by enzymic changes lower the quality of the concentrates and therefore should be prevented.

2. Basic factors involved in gelation and clarification of citrus concentrates are concentration of pectin, pectinesterase activity, pH, and bivalent ion concentration in these products.

3. Practical factors involved in gelation and clarification of concentrated citrus juices are fruit variety, quantity and type of pulp, degree of concentration, and storage temperature.

4. Possible methods for the reduction or prevention of gelation and clarification are modification and control of processing procedures, storage of frozen citrus concentrate at all times at temperatures of 0° F. (—18.0° C.) or below and inactivation of pectic enzymes by heat treatment.

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The Application of "End-Over-End" Agitation to the Heating and Cooling of Canned Food Products[a]

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New equipment has been developed for the heating, sterilization, and cooling of foods in sealed containers. Various products have been tested using the new end-over-end principle of agitation. The rapidity with which heat can be transferred to and from canned foods by this method is demonstrated.

A commercial-size batch-type machine for 603 x 700 cans, as well as a smaller prototype, were the first machines developed. The construction and method of operation of these is shown.

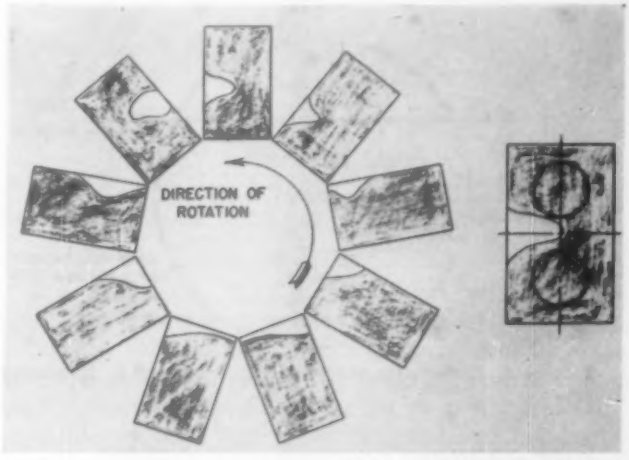
The quality of a given food product is related to the processing time and temperatures applied to the product during canning. It is generally agreed by food technologists that any improvment in the canning process which will decrease the time necessary for heating and cooling is desirable. Another variable which must be considered is the amount of mixing taking place in the container during the cooking process. The large majority of canned products are still being processed without any special agitation. In such cases the only mixing the contents receive is that caused by convection currents.

An increasing number of manufacturers are becoming cognizant of the advantages of mixing the can contents during heating and cooling. This is especially true with larger can sizes and when one is dealing with viscous semi-liquid products. Consequently there is growing recognition that the type of agitation is one of the most important factors to be evaluated in any study of heat transference.

Studies have been made by the Research Department of the Continental Can Co. *(1)* on the rate of heat penetration in cans agitated by a variety of methods. Parts of this study, which have been confirmed and extended, indicate that the end-over-end principle of agitation at controlled speeds of rotation has superiority over other methods previously reported.

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951.

End-over-end agitation is the motion imparted to a can when one end is in contact with the circumference of a revolving drum. Figure 1 gives a diagrammatic presentation of the method of rotation and the theoretical position and mobility of the contents of the can when it is rotated end-over-end at optimal speed.



(Courtesy of Continental Can Co.)

FIGURE 1. Theoretical position and mobility of the can contents when the can is rotated end-over-end at optimum speed where CF = G. On the right the turbulence created when void space traverses through center of contents is illustrated.

The mixing of the contents of the can is affected by the motion of the can and the amount of headspace in the can. This headspace or unfilled volume usually manifests itself as a bubble which has a different motion than the liquid in the can and thus acts as a mixing agent. It is apparent that the amount of headspace is an important variable in any can agitation system. In all experiments reported in this paper the gross headspace was 3/8 inch unless otherwise indicated and was measured at 150° F. (65.5° C.). The method used to measure the fill of the cans is shown in Figure 2.

Since gross headspace is determined by measuring from the top of the double seam to the level of the product in the can, the net headspace is about ⅛ inch less than the gross.

In order to obtain basic information on end-over-end cooling rates, a two-can version of an end-over-end machine was constructed. This laboratory unit, which is illustrated in Figure 3, is 46 inches in diameter and 12 inches in width.

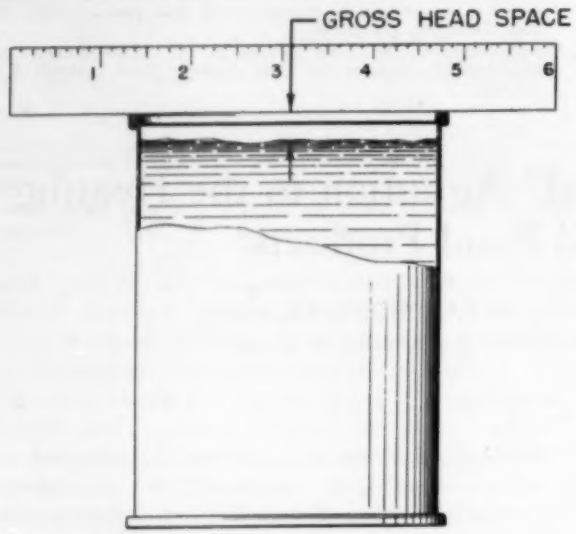


FIGURE 2. Method of measuring gross headspace.

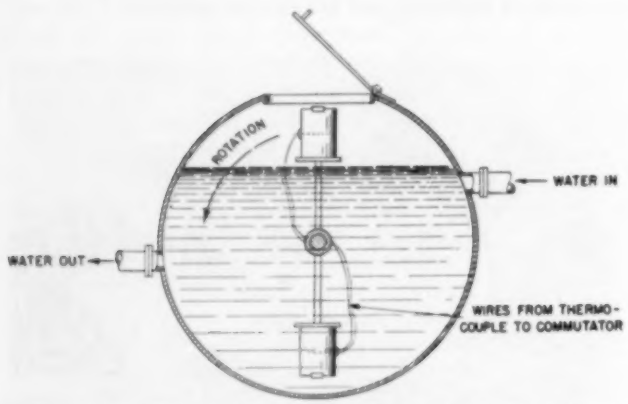


FIGURE 3. Schematic diagram of experimental laboratory cooler.

Water at a constant temperature of 70° F. (21° C.) was circulated through the unit and the level was adjusted so that it was one inch below the bottom of the can when the can was in its topmost position.

The speed of rotation and length of the axis of rotation were varied to determine the effect of each upon cooling rates. Thermocouples were installed through the side of the can so that the can center temperature could be measured. These thermocouples were connected to a recording potentiometer by lead wires extending through the drive shaft to a commutator.

In order to obtain preliminary data on the heat transfer rates of different products, cooling curves for water, tomato juice, orange concentrate, and corn syrup were determined. Figure 4 shows the cooling curves of these products at their optimum rotational speeds at a fixed radius of 6¼ inches.

Radius is measured from the axis of rotation to the bottom of the can. These results depict the relationship between the rate of cooling and the thickness and conductivity of the products. Table 1 lists the viscosity,

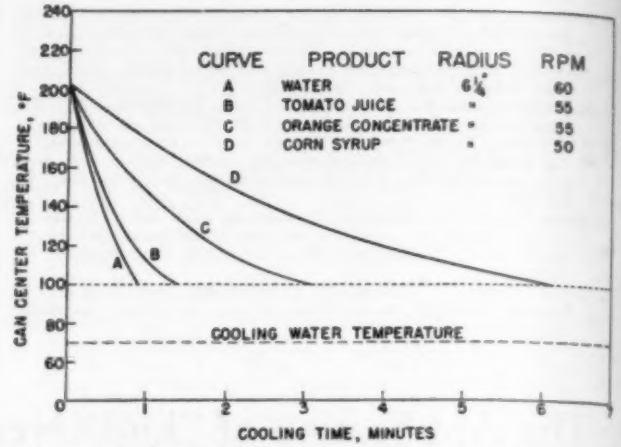

CURVE PRODUCT RADIUS RPM
A WATER 6¼" 60
B TOMATO JUICE " 55
C ORANGE CONCENTRATE " 55
D CORN SYRUP " 50
CAN CENTER TEMPERATURE, °F
COOLING WATER TEMPERATURE
COOLING TIME, MINUTES

FIGURE 4. A comparison of cooling rates at optimum r.p.m. for several products in 307 x 409 size cans.

TABLE 1

Physical properties of products for which cooling rates are shown in Figure 4

Product	Specific gravity at 68° F./ 68° F.	Solids content [b]	Viscosity in centipoises [c]		Cooling time [d]
			at 100° F.	at 200° F.	
		%			min.
Water	1.00	....	0.7	0.3	0.85
Tomato juice	1.025	6.6	12.0	6.0	1.35
Orange concentrate	1.285	58.1	280.0	111.0	3.00
Corn syrup	1.375	75.3	850.0	38.0	6.15

[b] From refractive index, using sucrose scale.
[c] Apparent viscosities, using Stormer Viscometer.
[d] Time in minutes to cool from 205° F. to 100° F. (96° C. to 38° C.) in 70° F. (21° C.) water at optimum r.p.m. and a radius of 6¼ inches.

specific gravity, percent solids, and cooling time of these materials.

It is apparent that thicker products cool more slowly. This can be attributed to less mixing in the more viscous materials and perhaps to the lower conductivity of the product.

It has previously been shown *(1)* that the distance of the can from the axis of rotation has a definite effect on the rate of heating. Figure 5 compares the effect of radius of rotation on the cooling rate of a No. 2 can of 6:1 orange concentrate when cooled from 205° F. to 100° F. (96° C. to 38° C.) in 70° F. (21° C.) water.

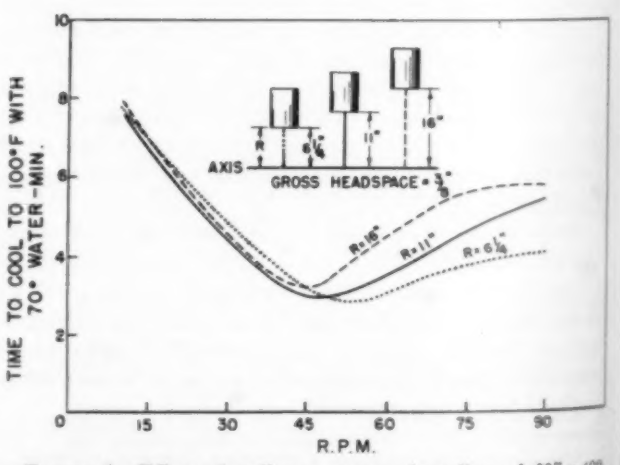


FIGURE 5. Effect of radius on rates of cooling of 307 x 409 cans of 6:1 orange concentrate at various speeds of rotation.

It is apparent that the optimum speed of rotation varies with the radius or rotation. It is also to be noted that as the speed of rotation increases beyond the optimum, the centrifugal forces created decrease the mobility of the contents. Thus, at the largest radius, 16 inches, there is a marked decrease in heat transfer rate at the higher speeds. The speed and radius of rotation must therefore be given important consideration in the design of commercial equipment.

In order to determine the effects of gross headspace in an end-over-end operation, 6:1 orange concentrate in No. 2 cans was again used. Gross headspace was adjusted to 1/8, 1/4 and 3/8 inch, respectively, at a fill temperature of 150° F. (65.5° C.). The curves shown in Figure 6 were obtained at a radius of rotation of 16 inches.

It is apparent that there is a marked decrease in the efficiency of cooling when there is only 1/8 inch gross headspace. An additional 1/8 inch greatly increases the efficiency. Further increases have relatively less effect on the cooling rate of this material although a minimum gross headspace of approximately 3/8 inch is desirable for some products.

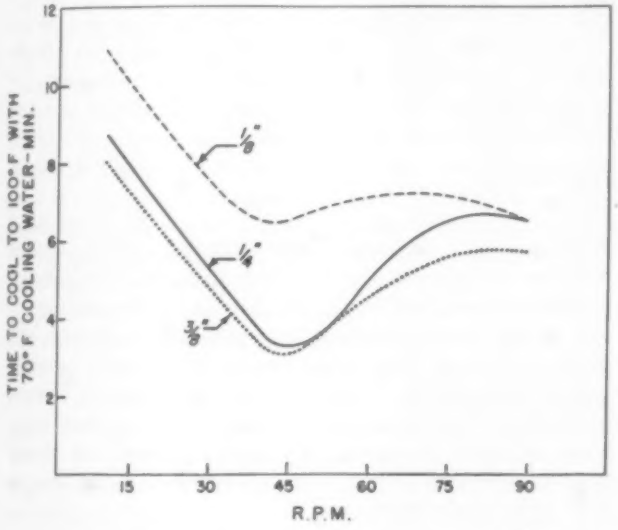


FIGURE 6. Effect of gross headspace on rates of cooling of 307 x 409 cans of 6:1 orange concentrate at various speeds of rotation.

Information about the effect of end-over-end rotation on the rate of heating during pressure sterilization of canned products was obtained by constructing a machine similar to that previously described by Clifcorn, Peterson, Boyd and O'Neil *(1)*. Essentially, this is like the unit illustrated in Figure 3 except that it is enclosed in a pressure shell. Figure 7 pictures the apparatus used.

To show the rate of heating of several food products in the laboratory machine, No. 2 cans containing water, tomato puree, brine-packed whole kernel corn, and brine-packed peas were heated with the retort at a temperature of 260° F. (127° C.). The heat penetration curves of these materials, at 75 r.p.m. and a radius of 4 11/16 inches, are illustrated in Figure 8.

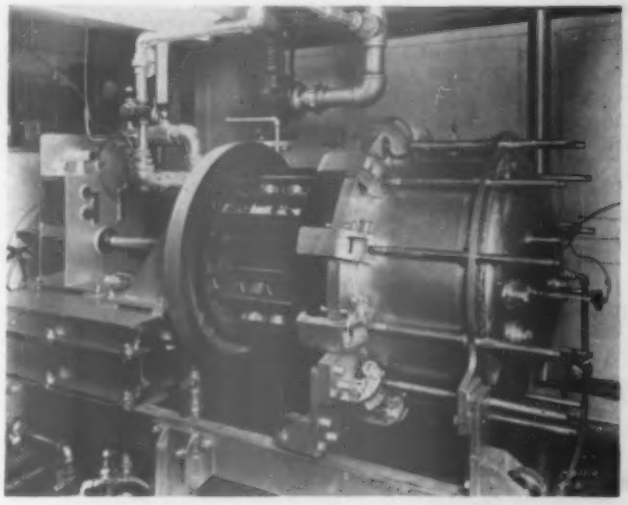


FIGURE 7. Laboratory end-over-end sterilizer.

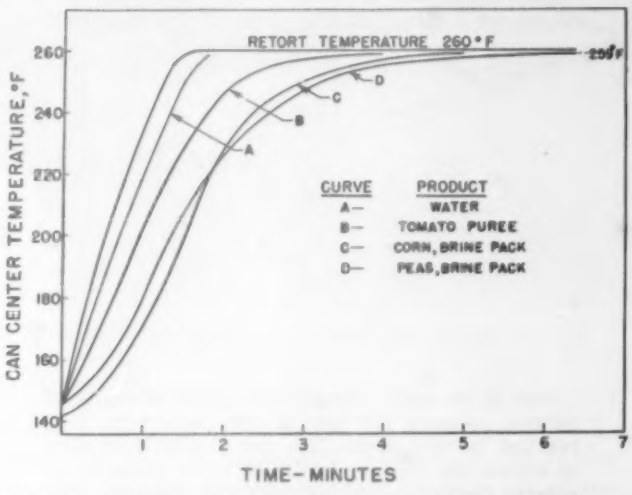


FIGURE 8. A comparison of heating rates for several products in 307 x 409 size cans at 75 r.p.m. and a radius of 4 11/16 inches.

It is evident that all of these products can be brought up to sterilization temperatures very rapidly.

Commercial application of the advantages of the end-over-end principle requires the design of special equipment. While such machines are not currently available, experimental units have been designed and are being built.

These machines provide means for rotating a quantity of cans in the end-over-end manner and facilities for automatically loading and unloading. They have two concentrically rotating structures, one within the other on a common horizontal axis and are enclosed in a pressure vessel. The outer one of the two rotating elements is designated the reel, and the inner is called the helix. They are mounted on concentric drive shafts so that the reel and helix may turn independently. During the loading and unloading cycle the helix is held stationary and the reel rotates. When fully loaded, the reel and helix are locked together so that they turn at the same speed during processing.

The reel is a relatively open structure arranged to guide the cans from end to end with the axis of the cans radial to the reel axis. The helix, which rotates within the reel, is edgewound on a central cylinder on which the inner heads of the cans rest. The radius of this cylinder is the distance from the reel axis to the bottom of the can and equals roughly one can height.

In loading the machine, a turret passes the cans through an opening in the end of the pressure vessel, inserting one can into

each of the passageways at the end of the rotating reel. Each can then starts to rotate in the reel passageway, and enters the first turn of the stationary helix. Continued rotation of the reel causes he inner end of the cans to follow the helical turns, and to progress along the length of the reel until the first can has reached the far end of the reel.

The clutches are now shifted to lock all cans in a fixed position by locking the helix to the reel. The vessel is closed and the reel is brought up to processing speed and the process cycle begun.

When the process is completed, the machine is stopped and the helix clutch is shifted to permit unloading of cans. A new batch of cans is loaded through the entrance at the same time that the processed batch of cans is unloaded at the opposite end. All functions and sequences of this machine are automatically controlled, requiring only initiating of the loading and processing cycles by the operator.

SUMMARY

1. Laboratory equipment for studying the heating, sterilization, and cooling of food, using the end-over-end principle has been described.
2. The relationship between the headspace, or unfilled volume of a can, and the rate of heat transfer has been studied and shows that adequate headspace is essential.
3. The variation of the cooling rate with the consistency of the product was shown for several liquid foods.
4. Varying the radius of rotation has an effect on the rate of cooling. For each radius there is an optimum speed of rotation.
5. Pilot plant equipment designed to rotate a quantity of cans and having automatic facilities for loading and unloading has been described.

Acknowledgment

The authors wish to acknowledge the contributions of Mr. Albert Olson, Mr. W. Gordon Brierley, Mr. Rudolph Lindow, and Mr. Oliver Tucker who collaborated in the design of the equipment described in this paper. Dr. M. K. Horwitt and Mr. G. K. Viall assisted in the analysis of the data and the preparation of the manuscript.

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The Quick Curing of Bacon[a]

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One of the major research objectives of the meat packing industry has been a reduction of the time required to cure meats. The use of nitrite in place of nitrate, and the introduction of artery pumping has reduced the curing time of hams and shoulders from weeks to a few days. Bacon bellies, which are not adapted to artery pumping, remain the last major pork cut which requires several weeks to cure. A method of reducing this time to 48 hours is described. A saving in amount of equipment required, in labor, and in capital, is also accomplished.

A reduction of the time required to cure meats has been one of the major research objectives in the meat packing industry. The rapidly fluctuating price structure of meat products combined with the comparatively high value of the products make large inventories of meat in process a threat to the financial solvency of meat packing companies in periods of declining prices. The first major step in the reduction of curing time took place about 25 years ago when the Bureau of Animal Industry authorized the use of sodium nitrite as a color fixative in conjunction with or in place of sodium or potassium nitrate. Prior to that time it required 50 to 60 days to cure a ham with a satisfactory color.

This authorization by the Bureau grew out of experimental work on the respective functions of nitrate and nitrite in the fixation of color in cured meats. The Institute of American Meat Packers, various meat packing companies, and the Bureau itself, were active in this experimental work *(1, 2)*. With the authorization of the use of nitrite it was possible to by-pass the slow and poorly controlled step in the curing process which depended upon the bacterial reduction of nitrate to nitrite. The curing time of hams was reduced from approximately 55 days to 35 or 40 days and the curing time of comminuted meats was reduced from several days to several hours.

The second major step in the reduction of curing time occurred with the introduction of artery pumping about 15 years ago. By injecting the curing solution into the arterial system of hams and shoulders, a very rapid distribution of the curing solution or "pickle" as it is called in the meat packing industry, is obtained. The time required to cure hams and shoulders is reduced to a few days by arterial pumping. This method is now in general use and the major percentage of hams on the market are cured in this manner. The exceptions are such specialties as Italian hams, Virginia hams, etc., in which a distinctive flavor is desired.

Unfortunately bellies do not lend themselves to arterial pumping and they remained the last major pork cut requiring considerable time to cure. The usual dry cure for bacon bellies requires 2 or 3 weeks depending upon the weight of the belly.

Various methods have been proposed and used for shortening the curing time of bellies. One of the oldest

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 19, 1951.

consists of what the industry calls stitch pumping. This method has been used chiefly for heavier and less desirable bellies. In stitch pumping the operator inserts a needle with a diameter approximately that of a lead pencil into the belly. The needle has a series of small holes extending from the point to halfway up the needle. With the stroke of a hand operated pump or by opening a valve when the pickle solution is under pressure, 2 or 3 ounces of pickle is injected. This is repeated in other parts of the belly. Some of the other methods for shortening the curing time have been based on the use of a concentrated curing solution continuously circulating over the belly surface, and on the use of hot curing solutions. All of these methods have some objections to them. Failure to secure uniform distribution of curing materials, poor penetration of sugar, and an increase in percentage of spoilage are some of the objections.

By injecting small amounts of concentrated curing pickle in numerous places with a hypodermic needle, it was found possible to cure a belly in 24 to 48 hours and obtain a uniform slab of bacon. The designing and building of a machine to do this mechanically and automatically was more difficult. One of the major difficulties was to secure a needle tough enough to withstand rough usage without bending or breaking. This needle must also be of sufficiently narrow diameter so that the puncture marks will not show in the finished bacon. The needle finally adopted was made from 304 or 316 stainless steel, which is a surgical stainless steel with a tensile strength of 180,000 lbs. The needles are hollow; the outside diameter is ⅛ inch, the inside diameter 0.040 inch. Four holes ¼ inch apart and at 90° angles are drilled in the needles. The holes are 0.018 inch in diameter.

Each needle is fed from its own cylinder to make sure that it delivers a uniform amount of pickle. The cylinders are bored into the lower casting of the injection unit which also serves as a reservoir for the pickle. The upper part of each cylinder is sealed with an O-ring, the lower end is sealed on the upward stroke by a ball valve. The cylinders are filled with pickle at the end of the upward stroke.

The plungers are housed in a movable upper casting which is controlled by a master cylinder actuated by compressed air. The amount of pickle delivered is controlled by the stroke of the master cylinder; this amount is easily adjusted.

The belly is penetrated by the needles by raising the platform on which it is placed and is removed from the needles by a stripper plate.

The first machine constructed held 60 needles. In this model the belly was placed beneath the needles by hand, raised onto the needles by a treadle arrangement, and pumped by opening a valve which admitted air to the master cylinder.

In later models the size of the pumping machine was increased to hold 101 needles. An indexing drive and a series of cam arrangements automatically convey the belly to the injection mechanism, charge the pickle injector, position the belly, and move the belly elevator (Figure 1). The injector stroke, pickle injection, stripping of the belly from the needles, and discharging of the belly are also automatically controlled.

With one machine, 200,000 pounds of bellies can be pumped in a 40-hour week. Curing time has been reduced from 2 or 3 weeks to 48 hours and an overall saving in labor of 25% is achieved. Other benefits are savings in curing space and equipment such as curing boxes.

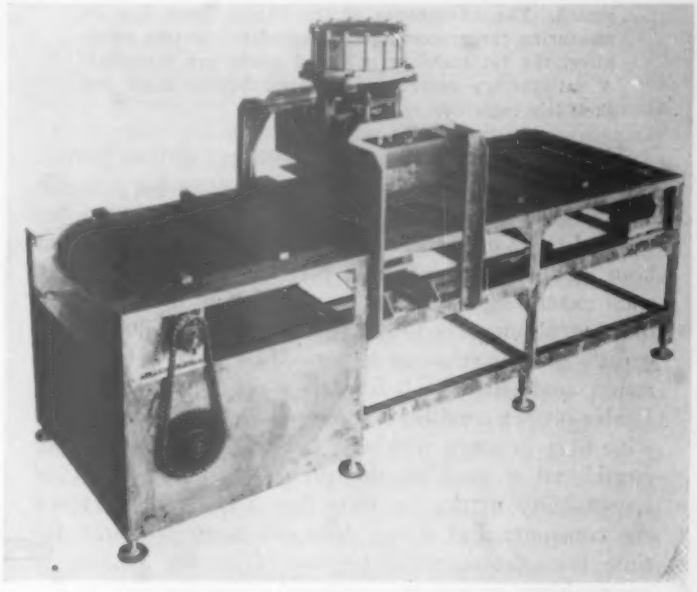

FIGURE 1. Photograph of a bacon belly pumping machine.

The question naturally arises, "How does this bacon compare with the conventional dry cured bacon?" To determine this, 20 hogs were selected on the cutting floor and the right and left bellies of the same hog identified. Half of the rights and half of the lefts were cured in the conventional manner, the other half were injection cured. A paired comparison preference study was conducted on slices taken from corresponding positions in the paired bellies. There was no significant difference between the two cures as determined by this test.

Samples of the paired bacon were held at a temperature of 28° F. (—2° C.), and were examined and tasted by a group of trained tasters at two week intervals for a period of ten weeks. No significant difference in appearance or in flavor between the two cures developed in that time.

During the past two years, over 20,000,000 pounds of bellies have been pumped by one packing company on three machines similar to the one described. Other machines have been installed in other packing plants both in this country and in Canada.

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Some Considerations in Measuring the Life Expectancy of Baked Goods[a]

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The difficulties involved in determining the shelf-life and stability of biscuit and crackers are presented. The advantages of the Schaal Oven Test in measuring the processing and ingredient factors which affect the fat stability in baked goods are discussed. A satisfactory correlation between Schaal Oven and shelf-life tests was not obtained.

The mortality tables of a human population have a great advantage over tabulated data covering the life span of an acceptable food product. In mortality tables the end-point of each subject is established by the exact hour of death indicated on the death certitficate. No such exactness is possible in establishing the end-point of acceptability of a food product. Food products vary greatly in their response to periods of storage, transportation, and shelf-life before they reach the consumer. Under proper conditions some products like cheese and wine may improve with age, but this period should be considered a part of the processing. The peak of acceptability marks the time that a food should reach the consumer and if this does not occur it marks the time that deterioration begins. The rate of loss of acceptability in various processed foods depends on the type of product, the method used for its preservation, and the ambient conditions to which it is exposed. Baked goods have a special list of factors that contribute to the termination of their shelf life. Bread and soft cakes are especially susceptible to staling and firming of crumb. If we limit our thinking to crackers and biscuits, the firming of the crumb becomes less important and other factors must be considered. Moisture changes in the product, foreign odors contributed by the package, staling or loss of desirable flavor, and rancidity development are the more important factors to consider.

Packaging materials are available to adequately maintain the low moisture level necessary in most crackers and biscuits so their crispness is not lost.

The extent to which foreign odors are absorbed from the package depends on the intensity of the odor and the duration of the exposure of the contents. Old merchandise may have an odor and taste characteristic of its paperboard carton. Solvents, adhesives, and inks may contribute foreign odors that reduce the acceptability of a product.

Staling, when referred to as meaning a loss of flavor, is most likely a result of oxidation of the flavor factors characteristic of the variety. Because baked goods absorb outside odors to concentrations that may exceed and overshadow the concentration of the desirable flavor in the product, this absorption may be confused with actual staling.

In the merchandising of crackers and biscuits, rancidity is generally not a serious problem if the fat from the product does not stain the package. When staining occurs, the fat in the package material is very susceptible to rancidity development. The rancid odor from the stained area of the package can, like any other foreign odor, be absorbed by the contents, causing them to be scored "rancid." We have examined the extracted fat from products thus contaminated and found peroxide values indicating a stable condition in the fat in the baked merchandise. When the fat was extracted from the stained area, its peroxide value was indicative of the rancid condition existing in the area. A close organoleptic examination of the package's contents near the stained area will show a higher "rancid" rating than in areas farther from the stained area. In following the development of rancidity in crackers and biscuits, any staining of the package presents an untenable sampling situation. Fat stability tests in the product must be conducted using non-staining packages.

As indicated above, rancidity occurrence and its control and measurement is only a part of the problem of shelf-life investigations. The factors arising in its study, however, are of general interest and justify further discussion. Crackers and biscuits, in which rancidity may occur, have a normal shelf-life extending over several weeks or months. Efforts directed toward improving processing methods or evaluating fats and fat anti-oxidants make it necessary to follow rancidity development over a considerable period of time. The technician is therefore justified in favoring an accelerated test for measuring rancidity development. Unless the accelerated tests can forecast with dependable accuracy what will happen to the fat during shelf-life, their use becomes difficult to justify.

The Schaal Oven Test *(1)* is the accelerated test most commonly used to estimate fat stability in crackers and biscuits. The sample is placed in a closed bottle or jar and held in an oven or cabinet at an elevated temperature, generally 63° C., until a rancid odor develops. This test has an important advantage in addition to the reduced time for rancidity to develop. When rancidity develops in this test it is generally definite, the odor is sharp, ketone-like and easily identified by an experienced operator. When the oven is held at still higher temperatures rancidity occurs in shorter time. Tests conducted on soda crackers at cabinet temperatures near the boiling point of water will show a rancid odor in a period of hours or, at most, a few days. This temperature is not far removed from temperatures occurring in the product during baking. This leads one to suspect that over-severe temperature and time exposure during baking would accelerate rancidity development just as it does in the high temperature Schaal Oven

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 19, 1951.

Test. This was demonstrated in experiments in which crackers were deliberately baked at higher than normal temperatures. Compared with the normally baked product in Schaal Oven Tests at 63° C., the high temperature bake showed a definitely reduced time to the rancidity endpoint.

When bottled samples are stored at room temperature, or shelf-life temperatures, an endpoint for the sample is difficult to obtain. This is indicated by the wide variability between replicated tests in contrast to a much lower variability between replicates at the higher temperature. This may be caused by a lower concentration of the rancid odors that develop in the bottles at room temperature, as the test is regularly conducted at 63° C. We have found that reporting the average of quadruplicate tests gives results of dependable accuracy. The endpoint on each bottle is determined by agreement between three operators experienced in detecting rancidity. When the test is conducted at room temperature, the greater variability between replicates means that in order to attain a comparable accuracy, more than quadruplicate tests should be used for each sample. As a matter of expediency we have found it practical to use the average of quadruplicates in all Schaal Oven tests. Since the higher variability at lower temperatures is apparently due to a lower concentration of rancid odors that develop in the product; the situation requires that the tests be conducted by individuals having low threshold levels for detecting rancidity. It would appear that evaluating fat stability in crackers and biscuits at room temperature in bottles would eliminate package influence. We have found this procedure no better than when the test is made in a good non-staining package. Since the package stability evaluation gives the more practical information, we have attempted to use it as the standard against which the usefulness of accelerated tests can be gauged.

Another factor favoring the Schaal Oven Test is the fact that the product under test can be broken up. This permits a thorough blending of the sample for replicated tests. Testing the packaged product, however, is done on the individual product units which vary in the degree to which they have been affected by the package and the extent of their respective heat exposures in the oven. The decision on the condition of the sample in the Schaal Oven Test is arrived at by smelling the air over the bottled sample. In shelf-life tests decisions are reached by smelling the package contents and eating the product to the extent of drawing air through it in an attempt to get a concentration of rancid odor great enough for identification.

Recognizing these factors that contribute to the difficulties in establishing when packaged merchandise is rancid, it is nevertheless necessary to submit it to a panel for appraisal. The panel must be trained in identifying rancidity and the members should be guided by adequate control samples in making their decisions. When a panel of twenty members periodically examines a sample stored at room temperature to follow the development of rancidity, eventually one member will report that the sample is rancid. Over a period of days, weeks, or months, depending on the rate and intensity of rancidity development, additional panel members will report the sample rancid. Eventually most of the members may report the sample rancid. From the time of the first "rancid" report until most of the members report "rancid," the panel has accomplished principally a classification of the rancidity threshold levels of its members. If this was accomplished over a period of one or two months, or more, what can we report as the fat stability endpoint of the sample?

If these taste panel results are to be handled as though the decisions might be right or wrong by chance only, then a chi square or critical ratio treatment of the data would be applicable. This would mean that 15 members of the panel should call it rancid before it is significantly rancid. A democratic way might be to call it rancid when a majority (11 of a 20 member panel) report rancidity. Those experienced in problems involving rancidity are inclined to think that the sample has reached its stability endpoint before either of the above interpretations would indicate.

To arrive at a more definite and reproducible endpoint in rancidity shelf-life tests, we have arbitrarily defined a sample as rancid when three of the twenty panel members report "rancid." Several packages are examined to determine whether the appraisal is a localized condition or representative of the lot. This definition of the endpoint means that only a small part of the panel is used in making the decision. By this procedure, advantage is taken of the lowest threshold levels in the panel. The larger panel is maintained so that we can select individuals having the low thresholds and a dependable reaction to rancidity. By using the panel in this manner, we have made of it a "sharpened tool" to eliminate some of the variability inherent in the problem.

A factor for projecting the results of the Schaal Oven Test into shelf-life expectancy would make the accelerated test definitely more useful. In testing a series of 60 samples with the Schaal Oven Test at both 54° and 63° C., we could not obtain significant correlation with the shelf-life evaluation of the packaged merchandise stored at 28° C. Without significant correlation, a factor for projecting the accelerated test values into shelf-life expectancy is not dependable. A positive correlation does exist, however, between the accelerated test and shelf-life test. We attribute the low degree of correlation between these tests to the complexity of the problem of determining shelf-life endpoints. The Schaal Oven Test affords an excellent means of differentiating the effect of anti-oxidant protection for the fats in baked goods. Our results have suggested that the increased fat stability indicated by oven tests conducted at 63° C. may exaggerate the actual protection the anti-oxidants give under shelf-life conditions. A thorough analysis of this indication is limited by the fact that stable fats do not deteriorate to rancidity within a shelf-life period short enough to prevent other factors from causing them to become definitely unacceptable.

Panel members experienced in following the development of rancidity in the Schaal Oven Test are generally able to detect incipient rancidity. Because rancidity

development at shelf-life temperatures is much slower than at the elevated temperatures, the decision in this type of test becomes more difficult. In working with packages affording some ventilation to the contents, the concentration of rancidity may never reach a level high enough for detection. Nevertheless, the dissipated rancidity odors accumulate in the product to make it unacceptable with no rancidity endpoint having been established.

We have briefly covered some of the ramifications encountered in an unsuccessful attempt to establish a factor for projecting the results obtained with Schaal Oven accelerated rancidity tests to shelf-life expectancy of the fat component of crackers and biscuits. Having encountered numerous difficulties, we have become more cognizant of the factors involved. The oven test cannot be used as a substitute for shelf-life evaluation. It does, however, provide a means of detecting and evaluating factors having a bearing on shelf-life, which we have been unable to establish in shelf-life tests.

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Development of a New Process for Curing Coffee[a]

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A new practical process for consistently preparing top quality green coffee has been developed. The new curing process depends on the substitution of controlled enzyme action for spontaneous fermentation, and substitution of rapid drying for slow and inefficient drying.

More than 80% of the adult population of the United States drinks coffee. We import over 2 billion pounds of green coffee every year to make about 250,000,000 cups of coffee per day. The art of brewing coffee is much discussed, as nearly all of us are self-styled experts when it comes to making a good cup of coffe. Agreement on the one best method of brewing coffee in the home may never be reached but within the coffee industry we have found general agreement with the conclusion that although the various process steps are very important, no combination of roasting, packaging, or brewing methods will insure a good cup of coffee unless one starts with good green coffee. In other words, a dominant variable in coffee quality is found in the green coffee.

It has long been known that soil, climate, altitude, and other indigenous factors influence the quality of green coffee produced in a given area *(3)*. With the exception of horticultural practices in the culture of the coffee trees, these factors are beyond control. The curing or preparation of the coffee bean after it has been harvested is, however, potentially subject to control and in an investigation over a period of years we have learned that a significant improvement can be made in coffee quality through control of the curing procedure *(1, 2)*. This study has led to the conclusion that much potentially good coffee at harvest is damaged in the preparation of green coffee. Present curing methods vary widely but nearly all require one to two weeks for completion. We have found that it is highly advantageous to speed up the curing process by the application of pectic enzymes *(4)* and, where practical, to utilize mechanical drying.

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A brief review of the coffee curing procedures now in vogue may be helpful in explaining the new process. Basically, there are two coffee curing methods; the "washed coffee" method and the "natural coffee" method. The washed coffee method, which is illustrated diagramatically in Figure 1, produces on the average the best coffee. Ripe cherries, which must be "selectively picked" because all of the fruit on a branch does not ripen at one time, are first "pulped" by machine to crack open and largely remove the outer covering, or

Figure 1. Washed coffee process. In this process ripe red cherries are picked. The skin and fibrous pulp is removed mechanically. The mucilage layer is digested, then removed by washing, leaving a pale yellow, clean parchment surface. The coffee is then dried and the parchment removed by hulling machines to produce the characteristic green beans ready for roasting.

pericarp. The pulped beans possess a mucilaginous coating (the parenchyma) which is allowed to ferment or decompose. After fermentation, the beans are washed in water and then dried on a patio or, less frequently, in drying machines. The dry bean has a thin papery covering called the parchment layer (the spermoderm) which is finally removed in a hulling machine to yield the finished green coffee.

The fermentation is a spontaneous one and is brought about by a variety of microorganisms. As might be expected, an uncontrolled fermentation of this sort often produces off flavors which are sorbed by the coffee and result in low grade green coffee. Such "off flavored" coffee, when roasted, yields a sour, rough, or rank brew.

The "natural coffee" method which is illustrated in Figure 2, is under still less control and is responsible for much of the really poor coffee produced today. In this process the unpulped cherries which are usually strip picked (Figures 3 and 4), and thus include underripe and overripe fruit, are allowed to dry on the patio until a moisture content of 10 to 15% is reached. At this point the outer layer, the dried mucilage and the parchment can be removed in a single hulling operation. The drying of natural coffee may require several weeks in bad weather and this is ample time for spoilage to occur in the warm coffee growing countries.

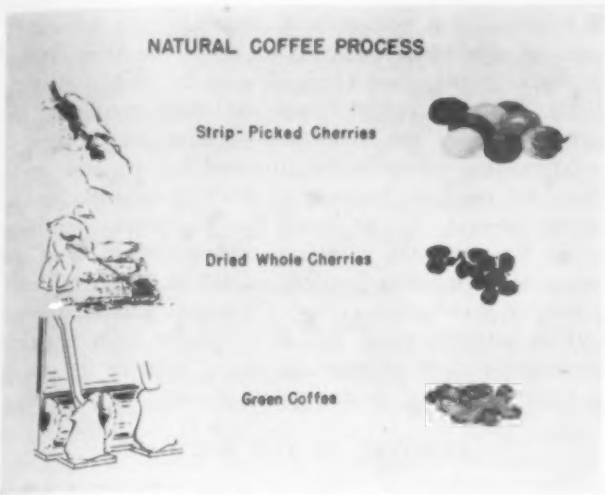

FIGURE 2. Natural coffee process. In this process, green, yellowish-red, red-ripe, blackish overripe, and brownish-black partially dried cherries are all picked together, and the whole fruit dried directly to a dark brown or black product. The dried skin, pulp, mucilage and parchment layers are removed by hulling machines to produce green beans ready for roasting.

METHODS AND MATERIALS

Our investigation of coffee curing has covered a number of years and in that time has gone through several stages with respect to methods and materials. Our pilot plant operation conducted in Brazil is a good example of an important stage of the work.

FIGURE 3. Strip picking of coffee. The picker is shown here removing the leaves, sticks and debris from the strip-picked cherries.

FIGURE 4. Selective picking of coffee. Measuring the day's picking.

The coffee plant. A washed coffee plant at Bom Jardim, Brazil, situated in and typical of the Zona de Mata region, was leased from the Brazilian Government in order to furnish a coffee supply, standard coffee processing equipment, and housing for pilot plant scale experimental work on coffee curing.

The existing equipment in the plant consisted of a receiving tank, storage tanks, a pulping machine (Figure 5), fermenting tanks, a washer, drying patio (Figures 6-8), hulling machine and hand picking tables.

Coffee cherries. Coffee cherries from within a radius of about ten miles of the plant, produced for the most part at an altitude of 2000-2500 feet, were utilized. They were brought to the plant by truck and mule-back on the same day on which they were picked and processed as promptly as possible, usually on the same or the following day. In a few instances it was necessary to store them until the third day. They were always stored under water to minimize deterioration.

Experimental equipment. The experimental drying equipment, which was partly designed and assembled at The Fleischmann Laboratories and shipped to Bom Jardim, consisted of a through-flow rotary dryer and its accessory duct-work, a steam indirect air heater and an oil-fired direct air heater, fans, control instruments and a 20-horsepower automatic boiler. This

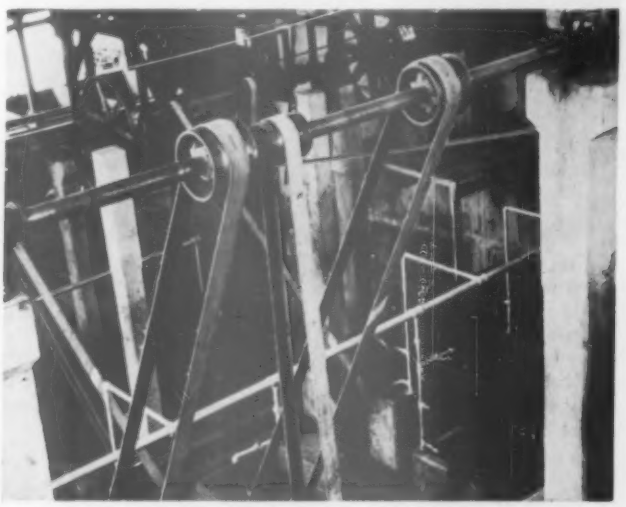

FIGURE 5. Pulping machinery. In a modern plant, such as this, the coffee is passed through three successive pulpers in order to do a thorough job.

FIGURE 6. Brick drying patio for sun drying. At the end of the day or when rain threatens, the coffee is gathered into heaps and covered with tarpaulins to protect it from dew or rain. Washed coffee in its light-colored parchment coating is shown in the background, dark-colored natural coffee in the foreground.

FIGURE 7. Drying of experimental lots of washed coffee. The lots in the foreground are being dried without washing after digesting the mucilage with enzymes. The lighter colored lots in the background were prepared in the same way except that they were washed.

FIGURE 8. Drying natural coffee. Note the dark color of the dried whole fruit.

experimental equipment was capable of handling 3800 lbs. of cherries or about 700 lbs. of finished green coffee per 24 hours.

Evaluation of green coffee. Coffee quality was evaluated by using the standard coffee industry cup test carried out by expert coffee buyers and a trained laboratory panel of 15 people.

THE PURPOSE OF THE CURING PROCESS

To most people the word curing signifies a beneficial process in which some new and desirable property is developed in a product. A careful study of the essential features of coffee curing as outlined above failed to reveal any such development or improvement. The sole function of the so-called curing process appeared to be the separation of the coffee bean from the whole cherry and the drying of the bean. It was concluded that if this interpretation were correct then there should be an opportunity to improve the quality of much green coffee by preventing or minimizing deteriorative changes during curing.

A series of investigations, starting with laboratory tests on ripe cherries flown up from the West Indies in thermos jugs and continuing with field studies in Haiti, Costa Rica, and finally in Brazil, confirmed the hypothesis that the bulk of the coffee on the tree is potentitally good coffee but much of it never ends up in the good category because of deterioration during the curing process. It was found that a process comprising rapid fermentation, washing, and dehydration of the beans to a moisture content of 10 to 12% uniformly produced good green coffee. Once this was established our objective became the development of a practical process for rapid economical curing suitable for use in the various coffee producing countries.

REMOVAL OF THE MUCILAGE

The fermentation of pulped beans, which is a step in the washed coffee process, is desirable because the mucilage has a great water-holding capacity and unless it is removed it retards the drying process. Normal spontaneous fermentation in commercial practice requires 24 to 48 hours depending chiefly on climatic conditions. During this fermentation the mucilage is digested either by enzymes naturally present in the coffee or by enzymes secreted by microorganisms which develop during the fermentation. An unfavorable fermentation frequently occurs in which souring and putrefactive bacteria develop. A study of commercially available enzyme preparations disclosed that pectic enzymes derived from molds are highly effective in digesting the mucilage. At a concentration of 0.2% of a commercial enzyme preparation, based on the weight of the pulped beans, complete digestion was accomplished in less than one hour at 24 to 25.5° C. (75 to 85° F.) as compared to an average of 36 hours required for completion of spontaneous fermentation. At a concentration of 0.025% (1/40%) the digestion could be completed in 5 to 10 hours depending upon the temperature. The latter quantity was found to be the most practical inasmuch as the time is short enough to prevent deteriorative fermentation changes and the quantity of enzyme needed was small enough so that its use was economically sound. At no time was it possible to detect any unfavorable effect on coffee flavor as a consequence of the enzyme treatment.

In practice the enzyme preparation is added as a dry powder to the pulped beans on which it is soon dissolved in the surface moisture. Temperatures up to 50 to 60° C. (122 to 140° F.) are tolerated by the enzyme. Hydrogen ion concentrations corresponding to pH 3.5 to 4.0 favor the most rapid action of the enzyme but the action is suitably fast at the natural reaction of pulped coffee beans (pH 5.0). A thorough and uniform dis-

tribution of the enzyme over the surface of all of the beans is desirable and this may be accomplished by either hand or mechanical stirring.

DRYING THE COFFEE

After removing the digested mucilage by washing, the next time-consuming operation is drying. This may be done by sun drying on a patio and sometimes by mechanical dryers. Sun drying requires one to two weeks depending on the weather, and damage to quality may occur as a consequence of the growth of molds and bacteria if the coffee is made wet by rain during the drying peeriod. Present methods for mechanical drying usually require 36 to 60 hours. Our experimental work showed that washed parchment coffee could be dried in about 4 to 6 hours both on a laboratory and on a pilot plant scale, and that the coffee thus rapidly dried is of top quality if the other curing steps are carried out correctly.

The more rapid drying in our pilot plant experiments was accomplished with a through-flow rotary dryer. Similar results can undoubtedly be obtained with any one of a number of modern efficient dryers. With a properly designed dryer, relatively high temperatures and correspondingly shorter times can be used without detriment to coffee quality. Compared to the usual coffee dryer, the new rapid drying method uses higher air temperatures, thus effecting higher drying efficiency and lowered fuel costs. Consequently, the cost of rapid drying is substantially lower than that of standard mechanical drying.

THE "PREFERRED" FORM OF THE NEW PROCESS

The choice of a method for curing coffee in any given area depends on such factors as climate, water supply, available labor supply, and degree of technical development of the area. For these reasons the actual coffee curing practice varies widely from country to country and from district to district. Where the above mentioned factors are not unfavorable, a possibility of applying our new process exists. This process will consist of the following steps:

1. Mechanical removal of the skin and part of the pulp of the coffee cherries to yield "pulped beans."
2. Pectic enzyme digestion at ambient temperature of the residual mucilaginous layer coating the pulped beans. The proportions of pectic enzyme used were 0.015% based on the initial weight of the cherries, 0.025% based on the weight of the pulped beans or 0.090% based on the weight of the finished dry green coffee in case of the pectic enzyme preparation used in these tests.
3. Washing of the pulped beans to remove the digested mucilage.
4. Mechanical drying in 4 to 6 hours of the digested and washed pulped beans (beans in clean parchment).
5. Hulling and grading by accepted methods.

Rapid curing makes it possible to pick coffee cherries one day and produce dry green coffee the next day with no chance for deterioration. The enzyme digestion is carried on during the night.

VARIATIONS IN THE NEW PROCESS

The pectic enzyme digestion of the coffee cherry mucilage is the most important step in the new curing process. Provided this step is employed, several variations in the process may be made with good results. For example, the washing step may be omitted in locations where water is scarce, provided the drying is started immediately on the completion of the enzyme digestion.

Another possible variation is to dry the beans in the sun, but only if the climate is such that there is little or no danger of rain damage or serious delay in the drying. If weather conditions are perfect, top quality coffee may be produced by sun drying and the cost of drying is low. In most coffee growing localities, however, there is risk of occasional rain, hence damage to quality through mold growth may occur and handling costs are greatly increased. Mechanical drying is to be preferred in most cases.

DISCUSSION AND SUMMARY

Brazil currently produces some 16,000,000 bags or 2 billion pounds of coffee annually, and we estimate that at least a billion pounds per year could be not only greatly improved in quality, but made fully equal to some of the superior coffee now produced in many Latin-American countries and eagerly sought by United States coffee buyers. High altitude quality can not be produced in Brazil where the highest producing areas do not exceed 3,600 feet. But altitude for altitude, Brazilian coffee can be made equal to other Latin American coffees.

The chief advantages of the new curing process employing enzyme digestion are as follows:

1. The new process is rapid, thus lowering capital costs for tanks and other coffee handling apparatus.
2. Because the new process is rapid, it prevents deterioration and raises the average quality of the coffee produced.
3. The new process furnishes a means for the postive control of coffee quality. Every lot is virtually certain to be of the highest possible grade.
4. The new process also raises the quality of coffee of marginal grade, i.e., the coffee produced from green or overripe cherries, some of which are always present. Hence, a higher portion of the total crop may be marketed as top quality coffee and a smaller portion as inferior low-priced grades.
5. The new process is economically sound. The increased market value of the crop much more than covers the cost of the enzyme and its application.
6. The scheduling of all operations is simplified because of the known time requirements for the digestion step.

Recent reports from Brazil and several Central-American countries indicate great interest in the new process, even in those countries now producing good washed coffee, because pectic enzyme curing offers the means for the first time of insuring the production of top quality coffee instead of the usual coffee of variable and unpredictable quality.

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Technics in the Automatic Control of Low-Temperature Vacuum Food Concentration[a]

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Vacuum concentration of foodstuffs becomes economically successful only when the operation is continuous and well balanced. An integration of automatic controls into a low-temperature evaporating system was studied, the objective being an uninterrupted, unsupervised process supplying a consistent product at maximum output. As a result of these studies, a control system, including especially designed components, was designed which would theoretically meet the dynamics and special requirements of this process. Particular emphasis is paid to the technics which were employed to get an optimum performance from the control system.

A switch from batch to continuous evaporation was an obvious way to meet production goals set by the highly attractive citrus concentrate market a few years ago.

But this fundamental change involved engineering problems which made transition far from simple. However, once solved, these very problems have turned into innovations giving today's continuous process distinct quality as well as quantity advantages over its batch counterpart.

This paper will discuss how coping with one of these engineering technics, process instrumentation, played a key role in the successful transition from batch to continuous processing at the Pasco Packing Company.

Prior to the 1949-50 pack, Pasco's concentrate production, while sizeable, funnelled through three batch vacuum pans. Instrumentation of these was relatively simple. Juice temperature was controlled during evaporation by a thermometer regulating preheating vapors. Hand refractometer readings told when the batch was finished.

A continuous evaporating system to more than treble production was planned. The evaporator selected was based on a design of the Florida Citrus Commission. Essentially, this is a three-stage thermocompression evaporator with a capacity of 1,174 gallons per hour of 42° Brix concentrate *(1)*.

Two of these three stage evaporators were constructed in Pasco's shops and housed in a new building. In addition, a large finishing pan was put in the old plant to set up the three batch units in a continuous system similar, in principle, to the new equipment.

BASIC INSTRUMENTATION CONSIDERED

While plans for these new evaporating facilities crystallized, a good deal of thought was given to automatic control. A round-the-clock production was scheduled and the ability of instruments to maintain uninterrupted processing was well appreciated. Further, a large continuous through-put required closer process tolerances than could be secured manually.

Automatic control of continuous evaporating systems of equal capacity has been an accomplished fact in the process industries for several years *(3)*. In surveying such systems it was obvious that their basic measurements would also apply in Pasco's new process.

Two primary instruments are usually found in conventional evaporator control systems. They are 1, the product density controller, which retards or speeds evaporation whenever product density deviates; and 2, the product level controller, which regulates feed to the evaporator in keeping with evaporating rate.

In effect, these two primary instruments interact to always maintain a desired product density under continuous evaporating conditions. Should product concentration decrease, for example, the density controller slows product removal. This, in turn, results in level build-up in the system and causes the level controller to call for less feed.

Through density and level interaction, then, the evaporator is automatically balanced. Its unbalance may have been due to a decrease in feed density. Or, perhaps, an increase in condenser water temperature. Either of these two causes can result in a "weak" product under fixed evaporating conditions.

Two other instruments are also desirable in a basic evaporator control system. These might be classified as "secondary" in that they are not necessary to automatic operation, but their presence helps smooth evaporation considerably.

They are 1, a system vacuum controller, which either measures the prevailing vacuum, directly or by inference, and controls water to the condenser; and 2, a product temperature controller, which establishes an optimum product temperature in the system by regulating its heating.

AVAILABLE EQUIPMENT INADEQUATE

The basic evaporator control concept seemed to apply to the new citrus process. But available measuring equipment was soon discovered to be unsuitable *(7)*. For one thing, very little had been done to make the needed instruments sanitary. In addition, new standards of precision were required by a product having little counterpart in similar industrial processing.

A brief survey of the then available level measuring equipment best illustrates the problem. A float type mechanism or a differential manometer were the usual

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[b] Present address: *Food Engineering*, McGraw-Hill Publishing Co., New York, N. Y.

ways to maintain level in an evaporating vessel. The former utilizes a hollow ball or cylinder which rides on or just below surface. Its position is conveyed by lever arm through a stuffing box to an air pilot controller.

Obviously, such a device was unsuitable from the sanitary standpoint. And its rather inflexible operating range and insensitivity made it a poor approach to the swirling product level characteristic of the new evaporator design.

Differential manometers overcome the inflexibility of a float type measurement. But such equipment has mercury in its manometer body and this, of course, precluded its use in a food process.

Density measurement seemed equally unapproachable. Most widely used technic involved a differential measurement of pressures needed to force air bubbles through a column of product and an equal column of water.

Accurate density measurement by a bubbler type system relies on fixed measuring conditions; exact column levels, unimpeded dip tubes, steady air pressure, etc. The maintenance that would be required to keep such a system functioning perfectly did not fit in with plans for continuous, unattended evaporation. Further, an external sampling system imposed an undesirable measuring lag and added problems of sanitation.

NEW EQUIPMENT DEVELOPED AND SELECTED

Pasco was thus faced with a need for two new approaches to the basic measurements of level and density. Special requirements for the level unit were: A, sensitivity, or ability to follow rapid system level changes; B, flexibility, or ability to measure and control level at varying heights in the evaporating body; and C, sanitary construction, design which precluded product contamination and allowed easy cleaning of the sensing means.

A post-war development in differential pressure measurement seemed to provide the answer. This was the so-called "dry" meter body, a sensitive opposed stainless steel bellows that could be substituted for the usual mercury meter body. Figures 1 and 2 show this unit and a drawing of its components.

The "dry" manometer seemed to offer all the sensitivity and flexibility of differential level measurement plus elimination of the contamination hazard. Further, it would simplify sanitation, an air purge on the measuring taps could keep product out of the lines as well as the meter body.

Density requirements seemed to add up in this manner: A, minimum lag, by measuring product just leaving the system; B, sensitivity and accuracy that would allow 0.2° Brix control; C, "in-line" construction that would provide simple sanitation; and D, dependability through a minimum of maintenance and supervision.

Brown Instrument engineers, who actively collaborated with Pasco in designing the evaporator control system, had to specifically create a density unit to suit these requirements *(4)*. Basically, the idea was to incorporate what might be called a "continuous hydrometer" reading of the product as it came from the pan bottom. A sanitary concentrate-measuring chamber

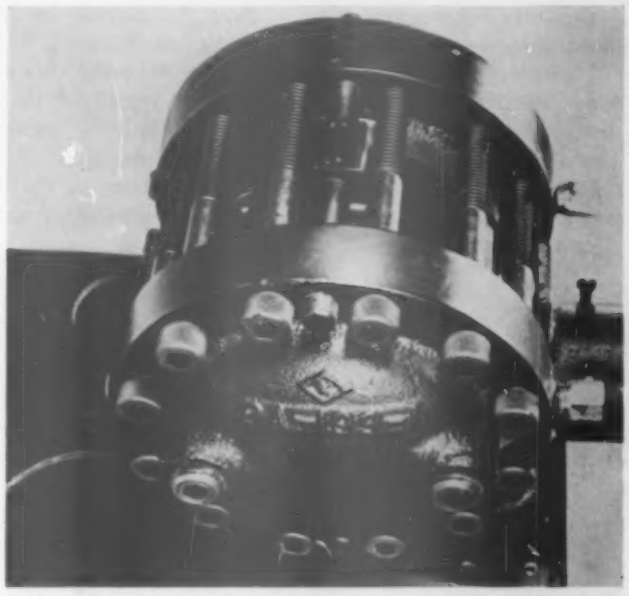

FIGURE 1. View of the "dry" type meter body. This unit is back-mounted and mechanically linked to a conventional differential pressure recorder-controller. High and low pressure connections are made in nipples between central flange bolts.

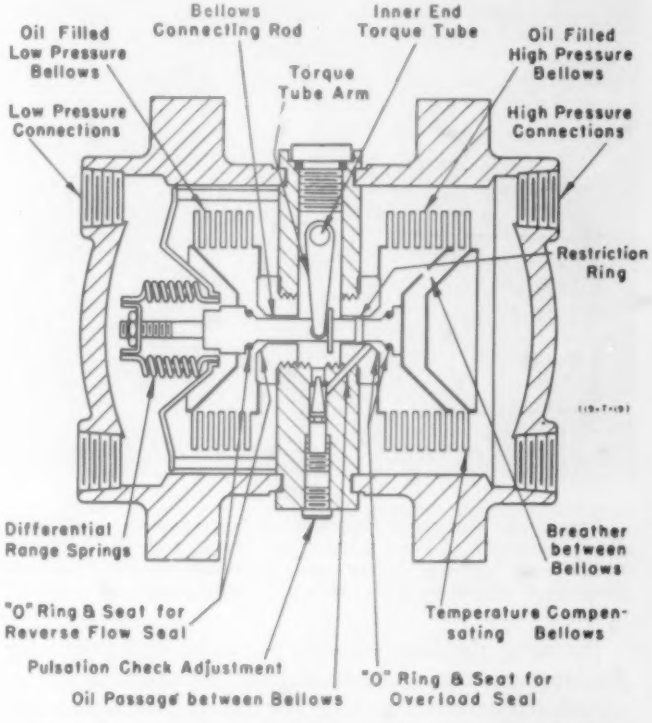

FIGURE 2. Cut-away drawing of "dry" meter body. Bellows, springs, and other parts which might conceivably contact food are stainless steel. Inner end of torque tube connects through instrument case and linkage to recorder pen.

was designed to be piped into the product stream. In this, a carefully sized stainless displacer, a watermelon-shaped, hollow unit, was suspended on a counterbalanced lever, brought out of the chamber by a sealing bellows.

Figure 3 illustrates this unit which effectively simulates a "line" hydrometer. Changes in position of its submerged displacer correlate with changes in buoyant force of the product (or its density variations). Figure

4 provides a cut-away view of how this action takes place *(6)*.

However, the difficult design job was to make this a stable measurement which would allow equally stable instrument control. This was accomplished by using a newly developed "force-balance" type transmitter. At the fulcrum point of the displacer bearing lever, a shaft was extended into a force-balance unit containing an air pilot and restoring or damping bellows.

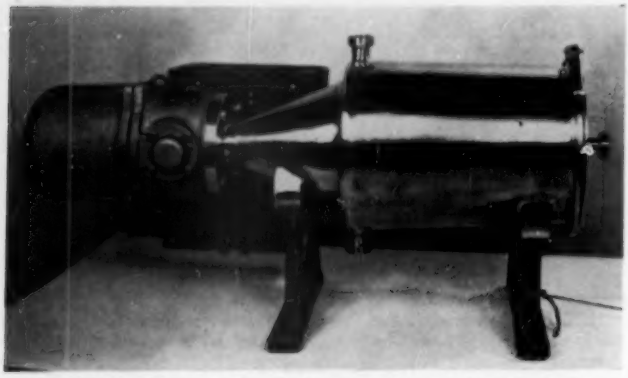

FIGURE 3. View of the sanitary continuous density detector. Inlet pipe is at right, outlets above and below the stainless steel sampling chamber. Black instrument mounted adjacent is the force balancer transmitter.

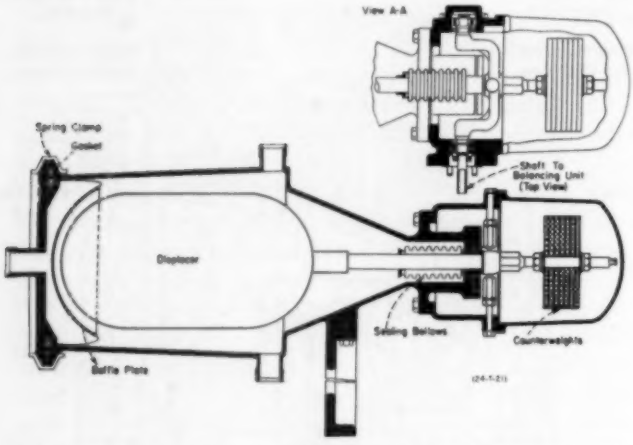

FIGURE 4. Cut-away drawing of the sanitary continuous density detector. Sloped cage construction and large groove stainless steel sealing bellows aid in sanitation. Force of displacer is conveyed through shaft to balancing unit.

By using the force-balance principle, any change in displacer position not only changes the transmitted air signal to a density receiving instrument, but also varies pressure on the restoring bellows. This latter action forces the displacer back to its original position. This provides a very stable and constant density measurement, with a minimum of space and moving parts in the sensing arrangement.

COMPONENTS OF INTEGRATED CONTROL SYSTEM

With instrument approach to density and level selected, the next problem was to integrate a system of controls with the physical design and thermodynamics of the evaporator.

A brief description of the evaporating system will serve to bring out some of its control requirements *(2)*. Although it has three evaporating vessels, the system functions as a single-effect evaporator in that all pans operate off a common vacuum header, which runs to an extra-sized thermocompressor barometric booster. In addition, high vacuum is achieved by each stage being served by a jet vacuum booster operating on 170 p.s.i.g. motive steam. A total vapor removal of 14,500 lb. per hour is accomplished, with compressed vapor liquefied by 1,600 gallons of 74° F. water per min. in the barometric condenser.

Juice to be concentrated is pumped at the rate of 2200 gallons per hour into the tangential inlet of the first-stage vapor separation chamber. The resulting 18° Brix juice in the first phase continues to be partially recirculated, thus mixed with incoming juice, and also fed into the second phase. Similar heating and recirculation of juice, this time at 33° Brix, occurs here. The third evaporating phase, also equipped with an individual recirculating pump, achieves a final juice concentration of 55° Brix. Concentrate is drawn off at the rate of about 380 gallons per hour, depending on the initial Brix of the raw juice.

Heating of the juice in each stage is by vapor removed from the pan by its associated jet booster. Motive steam, so added, raises vapor temperature to an efficient value for use in the juice heaters. A portion of these pan vapors also by-passes the heaters and goes directly to the barometric header.

It is apparent that evaporating system design in some ways simplified its control mechanics. For example, only a single level control was needed. Controlling juice into the first stage would stabilize level in all pans due to the systems' common juice line connection. Also, it was obvious that only one density controller would "set" the evaporating pace of the system through regulation of product draw-off.

Control of the juice evaporating temperature seemed a less tangible problem. Preliminary pilot evaporator studies showed that juice flavor was unaltered by vapor removal at 75° F. or less, if heater temperatures did not exceed 110° F. To secure maximum throughput and heat-efficiency, then, it would be necessary to maintain this balance.

Evaporating temperature correlates directly with the amount of vacuum being drawn in a system. So a regulation of vacuum by controlling the vapor condensing ability of the barometric condenser seemed of primary concern. Since the temperature of available water was essentially steady, the simplest means to gauge system vacuum would be through temperature rise in the barometric leg. This could be held at fixed value through the action of an air-operated valve in the condenser water supply line.

However, while vacuum would primarily determine the juice temperature, it was believed that a secondary control, or "trimming" was necessary in view of the steam-boosted vapor used in the heaters. A means of by-passing these vapors seemed desirable in order to prevent excess juice temperature in the heater. Also, this would quickly compensate for any rapid changes in evaporating temperature which would normally be slowly balanced by the vacuum control system.

Small-mass sanitary thermocouples were selected to measure product temperature in each stage for rapid response and sensitivity. An equally responsive electronic controller could thus effect rapid temperature control by positioning a butterfly valve in the vapor by-pass line.

Figure 5 shows the fully integrated control system which finally evolved. To simplify the diagram, control

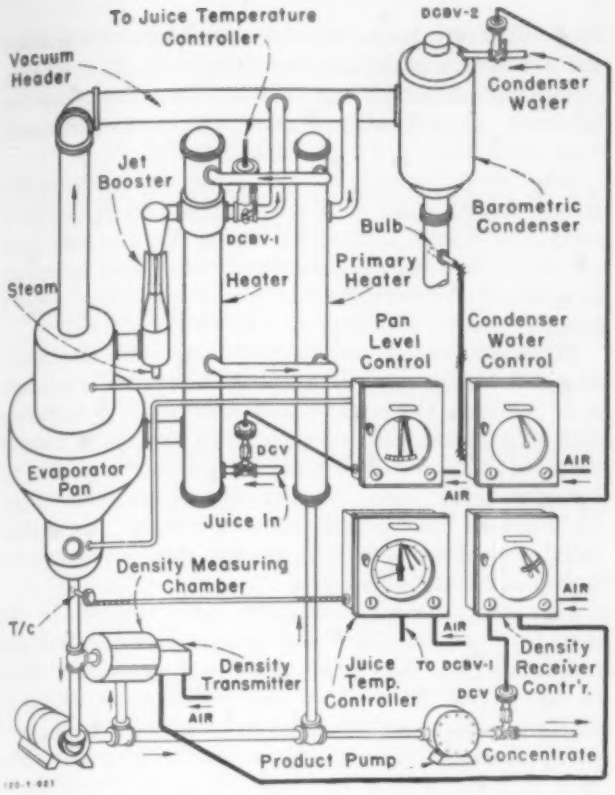

FIGURE 5. Schematic diagram of Pasco evaporator control system. Evaporating set panel actually carries two additional temperature measuring instruments for other stages.

components are shown as if the evaporator were only a single stage unit. However, the only additional equipment needed in the complete system would be temperature control at each stage.

At the start-up of the new evaporating system, then, automatic control was accomplished through the following components *(5)*:

1. An indicating pan level controller, calibrated from 0 to 20 inches of water, utilizing a "dry" opposed-bellows manometer. This unit is shown with high pressure tap at the pan bottom and low pressure tap at a fixed distance above in the vapor separation space. Instrument-controlled air positions a diaphragm-operated Saunders type valve in the juice inlet. An air purge of approximately one cubic foot per hour was placed on the pressure taps to keep them free of product.
2. A density control system, calibrated from 12° to 70° Brix, consisting of a sampling chamber, "force-balance" transmitter, and recording Brix controller. The product sampling chamber and associated transmitter is shown connected across the last stage circulating pump, thus gauging the product immediately as it leaves the pan bottom. Proportioned air is transmitted from the density pick-up to a panel-mounted recorder which is set to maintain 55° Brix concentrate from the system. Density changes cause this controller to throttle an air-operated Saunders valve in the draw-off line. Control includes automatic reset function to cope with any load changes which might occur in the evaporating system.
3. A barometric condenser temperature control, calibrated from 10° to 110° F. The bulb of this thermometer controller is shown located in the water leg of the condenser. Full throttling air control, with automatic reset, is used to position a large air-motor operated butterfly valve in the condenser water supply line.
4. A juice temperature controller, one per pan, calibrated from 25° to 150° F. The temperature-measuring sanitary thermocouple is shown installed in the pipe leading from the pan bottom. It is connected by rubber-covered leadwire to the panel-located electronic temperature controller, which incorporates full throttling, automatic reset type control action. The controlled instrument air positions an air-motor operated butterfly valve in the vapor by-pass to vacuum header.

Figure 6 provides a close-up of the density control installation. In the upper right, mounted across the circulating pump, is the measuring chamber. Note that its feed-in connection is on the pressure side of the pump. Just above the pump is the air-operated Saunders valve which throttles product draw-off. It is equipped with a large area powerful diaphragm operator to overcome the forces characteristic of Saunders type valves when throttled. On the pipe leading from the pan bottom, just to the left and below the density pick-up, the sanitary thermocouple can be seen.

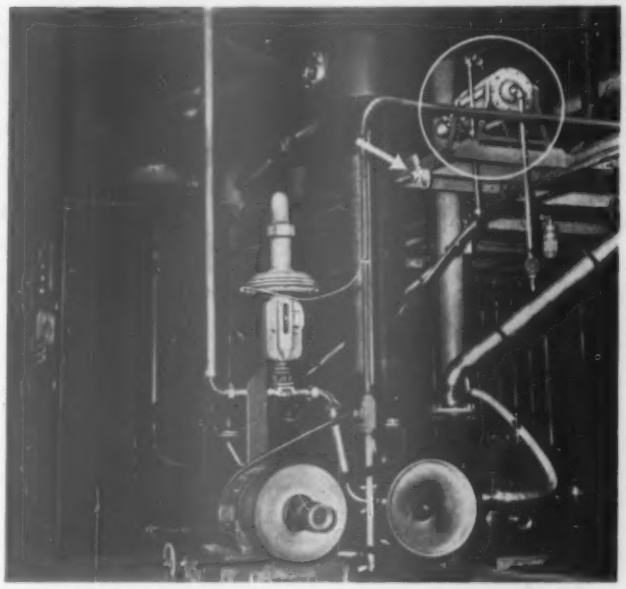

FIGURE 6. View of final stage product discharge showing density unit (circled) piped in around circulating pump, thermocouple (arrow) gauging temperature in downpipe, recirculation control valve (center) on product discharge pipe. Panel at left contains complete system of control instruments for evaporating set.

Figure 7 shows an air-motor operated butterfly type valve in the vapor by-pass line. A similar arrangement is used on the condenser water line. Such a hook-up is about the most effective way to control medium flowing in large pipes, plug-type construction becoming exceedingly costly and cumbersome in sizes of six inches or over. The valve pictured, and all other butterfly types, were fabricated in Pasco's own shops, thus making large pipe control all the more feasible from a costs standpoint.

PERFORMANCE OF THE SYSTEM

When the new evaporating plant was put "on stream," the basic soundness of its control system was soon demonstrated. The instruments took hold in the cal-

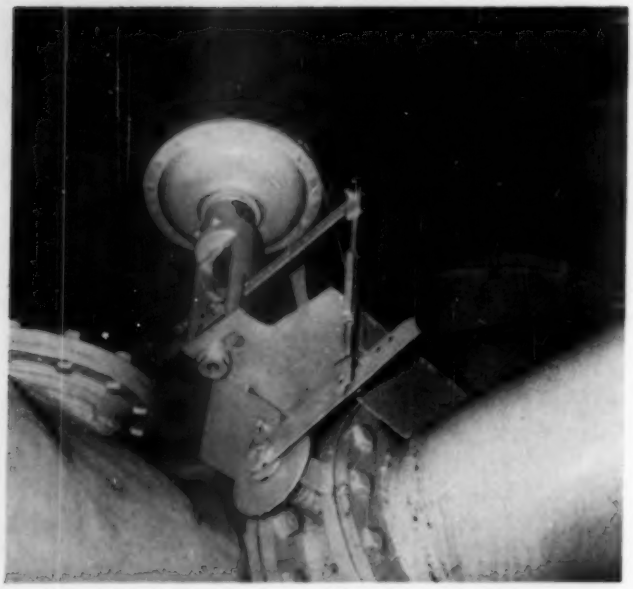

FIGURE 7. View of pneumatically operated butterfly-type valve in the vapor by-pass line. Simple fabrication of huge valves of this type allows control in very large pipe sizes.

culated fashion, and within a week's processing time only one attendant was needed to supervise automatic operation of the two evaporating sets.

However, as is always the case, the first few weeks disclosed some minor misconceptions and adjustments which had to be corrected and made before the control system could be viewed as perfected.

For example, the well balanced nature of the evaporator soon indicated that a sensitive "trim" of juice temperature was unnecessary. System pressure under the guidance of the barometric water controller was so steady that change in vapor by-pass valve position had very little effect on juice temperature. These valves were subsequently manually controlled by air operators, and the controller relegated to a simple recording function.

An obvious change for the current processing season was to remove the individual temperature recorders and substitute a six-point electronic stsrip-chart recorder for each evaporator. This now provides a single chart record of all juice and vapor temperatures on a wide 11-inch chart. The displaced electronic air controllers are being used, with new calibrations and sensing elements, for other jobs in the plant.

Problems also had to be solved in the juice level measuring system. Juice velocity, as it entered the pan, was so high that its swirling actually went above the top pressure tap. This caused fluctuating readings and excessive motion in the control valve. The problem was simply dealt with by locating the low-pressure tap well above the juice inlet.

A second problem soon appeared. Whenever the pan was shut down or vacuum removed, water was found to back up into the pressure taps and occasionally traces of orange juice would be found in the air-purge rotameters, causing their indicating ball to stick.

To eliminate this difficulty a positive air purge exceeding atmospheric pressure was placed on the system. This effectively keeps liquid or juice out of the lines and rotameters under any conditions. Further, it provides a means of checking pressure line connections for tightness. Considerable measurement errors can result from small leaks.

After these corrections were made, the level control system settled down to a trouble-free and satisfactory operation. Checking revealed that a constant pan level was being held to within one-half inch. This seems an exceptional performance in view of the small liquor quantity and its violently swirling nature.

Strangely enough, the most dubious unit, the newly designed density system, was found to be ideally adapted to its job from the start. Check readings of concentrate with a refractometer revealed that the chart control record was accurately holding the product to within an indicated $\pm 0.1°$ Brix. This condition was found to last for a full 24 hour period, with no need for the anticipated shut-down and adjustments that a newly conceived unit usually requires.

However, greater readability was desired in the density controller chart and first improvement in the unit involved a "spot" calibration to the narrower range of 40° to 70° Brix. This required a recalculation of displacer weight and a careful insertion of two and one-half pounds of solder into the stainless steel oval. Technics learned in this field calibration have resulted in considerable improvements in the adjustability of similar density units built for the current season.

One thing must be noted about this process density control technic. While the control system will ostensibly hold the product concentration to within as little as plus or minus 0.1° Brix for a long period of time, the resulting chart record cannot be interpreted as a quantitative evaluation of true Brix. The control system will reproduce its measurement and control at a set figure admirably, but it will not simulate the reading of an accurate refractometer.

In other words, the process control technic is actually controlling specific gravity and is not compensating for variations in Brix due to changes in anhydrous citric acid in the concentrate. Because of this acid factor, it may be necessary to adjust the control setting of the density system at intervals to correct for any acid variations in the fruit being run at the time.

CONCLUSION

The advantages of any automatically controlled evaporator should be summed up in one word: economy.

At Pasco this objective is reflected in three underlying reasons for going into extensive automatic control of its new continuous vacuum concentrating process.

1. Controls were applied to keep the evaporator in balance and do away with expensive shut-downs which can frequently occur during heavy processing.
2. Controls were applied to confine the density of concentrate to a fixed value, thus eliminating costly over-evaporation and equally costly reprocessing.
3. Controls were applied to remove the need for the constant manual attention required by the uninstrumentized evaporator.

Two seasons of successful low cost processing have borne out the soundness of this fully-planned integration of engineered control into a new evaporating plant.

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Determination of Sulfite in Dehydrated White Potatoes by Direct Titration

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(Manuscript received April 2, 1951)

A modification of the direct titration method of Prater, Johnson, Pool, and Mackinney is suggested for determination of sulfite in dehydrated white potato. The principal change is use of formaldehyde instead of acetone as the sulfite-binding agent in determination of non-sulfite reducing substances. The "fleeting end-point" is thus largely avoided and the accuracy of determinations by inexperienced operators is improved.

Recent events have greatly stimulated the purchase of dehydrated white potatoes by the Armed Forces. Sulfite is added before or during drying to minimize heat age. Determination of the sulfite content of the dehydrated product is necessary since enough must be present to retard browning but excessive amounts impart an undesirable flavor.

The Monier-Williams distillation method *(3)* has long been considered the most reliable method of determining sulfite in biological materials,[b] and the Thompson and Toy modification of this procedure *(7)* is currently included in military specifications *(2)*. However, for processing control a more rapid method is needed. Rapid direct titration methods have been developed for dehydrated vegetables in piece form by Prater, Johnson, Pool, and Mackinney *(5)*, and by Reifer and Mangan *(6)*. The latter method requires close attention to each determination and appears to be more time-consuming than that of Prater and coworkers. The Prater et al. method gives satisfactory results when operators are experienced in its use, but low and uncertain values are often obtained by inexperienced operators. This is due to the so-called "fleeting end-point" in titrating the acetone "blank" for determination of non-sulfite reducing substances. In this paper a modification of the Prater et al. method which avoids this "fleeting end-point" is described.

In the Prater et al. method the sulfite is extracted from the dehydrated vegetable by an alkaline solution, the extract is acidified, and the total reducing power determined by titration with iodine. Non-sulfite reducing materials are determined in a duplicate "blank" sample in which the sulfite is "bound" by acetone. The difference between the two titrations is a measure of the sulfite present. In the first titration the blue starch-iodine color will persist for several seconds or perhaps a minute, depending on the excess of iodine present. But in the acetone sample the end-point may disappear in a fraction of a second, as a result of rapid dissociation of the acetone-sulfite complex.

The rapid fading can be largely avoided by use of a binding agent, such as formaldehyde, which forms a more stable complex with sulfite than does acetone. Formaldehyde is used in the direct titration procedures of Reifer and Mangan *(6)*, and of Ponting and Johnson *(4)*. It was considered by Prater and co-workers and gave satisfactory results with some commodities but was not used because of its odor and because results with dehydrated cabbage were consistently 5 to 10% higher than those obtained by the Monier-Williams procedure. Reifer and Mangan obtained results with undeteriorated dehydrated cabbage, using formaldehyde, which were in good agreement with those obtained by the Monier-Williams procedure. They suggested that larger amounts of formaldehyde than were necessary may have been used by Prater et al. and that this may have been the cause of the higher results obtained.

These reports thus suggested that the fleeting end-point could be avoided and more definite and reliable results obtained with the Prater et al. method if formaldehyde were used as the binding agent, at least in

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[b] Recent work by Mangan and Doak *(1)* has shown, however, that the Monier-Williams method for determining the sulfur dioxide content in dehydrated foods is not specific, and indicates that, at least in the case of deteriorated dehydrated cabbage, the iodometric method with formaldehyde gives more correct results.

the case of dehydrated white potato. Preliminary trials were conducted and the results agreed well with those of the Monier-Williams procedure. Further work on choice of binding agent, method of extraction,[e] duration of alkaline treatment, amounts of reagents, and similar factors led to the following procedure, which differs from the Prater et al. method primarily in that formaldehyde is substituted for the acetone. Although this procedure was originally developed for dehydrated potatoes in piece form, it has been found applicable for potato granules, although reduction of the extraction time was necessary.

ANALYTICAL PROCEDURE

Preparation of sample. For dried diced potato the sample is ground, preferably through a Wiley mill equipped with a 2-mm. screen. If such a mill is unavailable, the sample may be prepared as follows by the procedure used for the moisture sample in military specifications:

Grind a 100-gram sample of diced potato in a blendor at top speed for one minute. Retain for analysis that portion passing through a 20-mesh but retained on a 40-mesh screen. Analysis has shown that this portion is representative of the whole sample.

Potato granules require no preparation.

Extraction and titration. For the analysis of dehydrated diced potatoes weigh two 8-g. samples of the ground material into 600-ml. beakers, add 400 ml. of water and 5.0 ml. of 5 *N*. sodium hydroxide to each. Stir gently, being careful not to beat air into the solution, and let stand for 20 minutes. To one of the samples add 7.0 ml. of 5 *N*. hydrochloric acid, stirring to avoid local acid concentration. Add 10 ml. of 1% starch solution and titrate immediately with 0.02 *N*. iodine to a definite dark blue color. It is important that the acidified sample be titrated at once, before recombination occurs. The titrations are best made with a mechanical stirrer carrying a propeller with broad blades having a steep pitch. This type of stirrer can be operated at a speed that will quickly incorporate the iodine into all parts of the solution without beating air into it. The potato particles adsorb some iodine and give the solution a grayish cast. This color should not be mistaken for the true end point. Iodine should be added until a definite dark blue color is obtained. This titration measures the total iodine reducing value of the sample.

To determine the reducing material other than sulfite, the second sample is acidified in the same manner; 10 ml. of formaldehyde (about 36%) are added to bind the sulfite; and the sample is allowed to stand for 10 minutes. At the end of this period, using the mechanical stirrer for mixing, titrate rapidly, preferably with the stopcock fully open until near the end point and then with increments of approximately 0.1 ml. added in quick succession until a dark blue color persists for at least 15 seconds. When granules are used add the 400 ml. of water, stir gently, and let stand 2 minutes; add the sodium hydroxide, stir gently, and let stand 1 minute; immediately acidify and titrate. Low results, due possibly to oxidation associated with the very large surface area of potato granules, will be obtained if this timing is not followed.

The alkaline mixture used to liberate the bound sulfur dioxide is that recommended by Prater et al. It is essential that the alkali, and later the acid, be measured accurately to insure a final pH of 2 to 3. This pH is preferred for the iodine reaction and the sulfite-formaldehyde complex is stable enough for a rapid titration.

The titration of the non-sulfite reducing materials should be made rapidly, as directed under Analytical Procedure. A slow titration will result in the reaction of a small part of the sulfite, due to decomposition of the sulfite-formaldehyde complex.

Calculation. Assuming that the sample weight is 8 g., calculate the sulfite content as follows:

[(Ml. of iodine to titrate sample) — (ml. of iodine to titrate sample + binding agent)] × normality of iodine × 4000 = p.p.m. sulfiite present (sulfite as SO_2).

COMPARISONS WITH MONIER-WILLIAMS METHOD

Effect of various sulfite-binding agents. In appraising the suitability of various possible sulfite-binding agents, an extensive comparison of the Monier-Williams and direct titration procedures was conducted. Formaldehyde, acetone, and glyoxal were the agents used.

Ten different lots of dehydrated diced potatoes were used. Some of these had been prepared in the pilot plant at this Laboratory; others were obtained from various manufacturers. Some had been sulfited by combustion gases in direct-fired tunnels, while others had been sulfited by sulfite spray or dip prior to drying.

Determinations by direct titration were performed by 7 operators. Three of these were completely inexperienced with the technique; operators 1 and 4 had had considerable experience. Each was given a copy of a procedure essentially the same as the one above and was allowed to work without further instruction other than that where indicated in his outline, 40 ml. acetone, or 10 ml. glyoxal was to be substituted for the formaldehyde. The samples were ground and mixed before they were submitted to the collaborators, and were held in an atmosphere of nitrogen until used.

Of the sulfite-binding agents tested, formaldehyde gave average values most closely agreeing with those of the distillation method (Table 1), the average values ranging from about 17% low to 4% high for formaldehyde, 39% low to 6% low for acetone, and 22% low to 6% low for glyoxal. Actone gave the poorest agreement between operators, and all operators reported difficulty with the acetone end-point.

Titrations by an experienced operator. Further comparisons were conducted to test the formaldehyde procedure in the hands of an experienced operator. A single operator, who had previously performed about 150 of these titrations, made replicate determinations on 17 samples. The results are shown in Table 2.

The range of duplicate and triplicate titrations varied from 2 to 23 p.p.m. for the dice and from 0 to 17 p.p.m. for the granules. With sample "p", on which 12 replications were performed, the range was 34 p.p.m. and the standard deviation 12 p.p.m. (3% of the sulfite content of the sample). In comparison with the Monier-Williams results, the average of the titration values ranged from 37 p.p.m. low to 13 p.p.m. high for the dice, and from 13 p.p.m. low to 26 p.p.m. high for the granules.

[e] On the basis of Ponting and Johnson's work with pure sulfite solutions, considerable error from autoxidation during the 20-minute extraction in alkaline solution might be expected. This was not observed. The results obtained with the Prater et al. method of extraction agreed as well with those of the Monier-Williams procedure as did results with Ponting and Johnson's 30-second alkaline treatment (following extraction by soaking for 20 minutes at pH 4.5 in tartrate buffer or in tartrate buffer plus 20% sodium chloride solution). Evidently there is too little oxygen dissolved in the solution to cause error, or the potato contains substances which inhibit autoxidation.

Preparation of the extract in a Waring Blendor was found undesirable because the finely divided potato absorbs so much iodine that determination of the end-point is quite uncertain. The end-point is easily recognized if extraction is by soaking rather than by blending, particularly if the "fines" are removed from the ground material before the sample for analysis is taken.

TABLE 1

Determination of sulfite in dehydrated diced white potatoes by direct titration when sulfite is "bound" by acetone, formaldehyde, or glyoxal, and by the Monier-Williams method

Method	Sulfite content as p.p.m. SO_2[d]									
	Sample									
	a	b	c	d	e	f	g	h	i	j
Monier-Williams, volumetric	190	630	315	315	2980	240	290	235	250	320
Monier-Williams, gravimetric	200	640	315	310	2920	235	275	235	240	.....
Titration										
Binding agent: acetone										
Operator										
No. 1	.....	670	260	335	.....	.....	200	230	200	.....
No. 2	.....	.....	175	.....	.....	.....	.....	.....	95	.....
No. 3	.....	.....	.....	.....	.....	.....	.....	.....	.....	260
No. 4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
No. 5	125	570	340	220	.....	.....	190	235	170	.....
No. 6	.....	640	280	275	.....	185	245	185	155	.....
No. 7	.....	520	160	.....	.....	.....	.....	.....	140	.....
Averages	.....	600	243	277	.....	.....	212	217	152	.....
Binding agent: formaldehyde										
Operator										
No. 1	215	670	295	235	3180	220	300	280	260	345
No. 2	155	645	275	270	2980	225	250	235	195	.....
No. 3	.....	.....	.....	.....	.....	.....	.....	.....	.....	315
No. 4	.....	580	320	310	2800	.....	290	250	.....	340
No. 5	170	625	370	295	2945	.....	280	275	215	.....
No. 6	.....	660	325	325	.....	210	295	185	195	.....
No. 7	.....	590	240	.....	.....	.....	.....	.....	170	.....
Averages	180	628	304	291	2976	218	283	245	207	333
Binding agent: glyoxal										
Operator										
No. 1	190	630	305	240	3015	215	270	260	245	.....
No. 2	140	590	265	275	3035	220	220	220	180	.....
No. 3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
No. 4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
No. 5	160	620	360	285	3000	.....	270	255	185	.....
No. 6	.....	645	275	270	.....	200	250	180	170	.....
Averages	163	621	279	268	3017	212	253	229	195	.....

[d] All individual values are averages of two or more closely agreeing replicates.

TABLE 2

Comparison of the formaldehyde titration method with the Monier-Williams gravimetric method. Titration by an experienced operator

Sample	Sulfite content, as p.p.m. SO_2					
	Titration				Monier-Williams	
	Individual values			Average	Individual values	Average
Dice:						
k	139	141	.....	140	147 149	148
l	658	664	.....	661	645 651	648
m	179	183	.....	181	191 193	192
n	572	581	595	582	594 610	602
o	346	351	357	351	360 370	365
p	(403-437)[e]		.....	420	431 446	439
q	681	689	691	687	717 730	724
r	640	646	653	646	660 662	661
s	339	347	353	346	352 360	356
t	30	33	38	34	48 57	52
Granules:						
u	93	93	.....	93	84 89	86
v	113	113	.....	113	110 106	108
w	220	237	.....	228	219 216	217
x	405	417	.....	411	396 408	402
y	454	446	.....	450	466 459	462
z	180	178	.....	179	194 191	182
7	237	238	.....	238	212 212	212

[e] Twelve replicate values for sample "p" had an average of 420, a range of 34, and a standard deviation of 12 p.p.m.

DISCUSSION

On the basis of the experiments reported in Table 1 formaldehyde and glyoxal appear to be preferable to acetone as sulfite-binding agents. Of these, formaldehyde may be preferred because it is inexpensive and readily available; glyoxal is less convenient to use because of its high viscosity.

The data show that the formaldehyde procedure gives values which are reasonably precise and in reasonably good agreement with the Monier-Williams method. The procedure suggested appears to be well adapted to use in control laboratories and inspection stations.

Although potato granules pass a 70-mesh screen, they titrate in a very satisfactory manner. Samples of dice of this fineness prepared by grinding or blending adsorb iodine and make accurate titration impossible.

Acknowledgment

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Comparison of Low-Temperature Evaporators[a]

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The various types of low-temperature evaporators are outlined briefly, and the process and product differences are compared. The problem of choosing an evaporator is discussed from the point of view of the purchaser. Factors such as utility requirements, first cost versus operating cost, range of operation, hold-up, insurance coverage, and waste disposal are covered. The questions of ease of operation and special requirements involved in start-up and shut-down are brought out. The type of instrumentation is discussed and several special cases are considered. A discussion of requirements for sanitary design, problems such as hesperidin build-up, and method of cleaning is given. A particular case involving the choice of an evaporator for an existing plant is studied.

Three distinct types of low-temperature evaporators are in general use today. These are single-effect single-pass, single-effect with recirculation, and multiple-effect with recirculation. Each type has been fully described in the literature *(3, 5, 6, 7, 9)*. For each main type of evaporator there is another choice to be had, in that the water vapor pumping system can be either a steam recompression system or a refrigeration cycle. Here again the pros and cons of each system and the details of design have been discussed thoroughly elsewhere *(1, 2, 4, 5, 8)*.

In terms of low initial investment and low operating costs, the multiple-effect units are most attractive, followed by the single-effect recirculating type and the single-effect single-pass. It might well be asked why there is any remaining interest in the single-effect single-pass system. Units of this type are still in operation on citrus juices in one of Minute Maid's plants. The evaporators are tall cylinders 30 inches in diameter and the juice flows through 14 of these towers in series *(9)*. If operated with the minimum levels, they can concentrate 1,000 gallons per hour of fresh juice at 50° Brix (percent solids) with an average transit time for any increment of juice of only six minutes. The product temperature does not exceed 60° F. (15.5° C.), and only the last two towers contain material of high viscosity. By removing towers from the line the capacity of the system can be lowered to 300 gallons per hour without changing other operating variables. By contrast, comparable double-effect units have a transit time of about 30 minutes, which grows proportionately longer as the feed rate is reduced. The general temperature levels are 75° F. (24° C.) in the first effect and 57° F. (14° C.) in the second effect. The first effect contains a considerable quantity of highly viscous product which, because of its low heat transfer coefficient and the higher temperature, is more sensitive to thermal damage. While the advantages of the single-effect single-pass unit no longer seem necessary for citrus juices, there may be other products for which they are desirable.

In order to limit the number of combinations which can be considered, a comparison of only a double-effect steam unit with its refrigeration cycle counterpart will be made. Table 1 shows the utility requirements for units with a capacity to evaporate 10,000 pounds of water per hour. The figures in the table do not include supplementary equipment such as water circulating pumps for the steam system or the sub-station equipment for the refrigeration unit. The units are assumed to be complete, ready to operate, once the utilities are supplied. With the wide choice of equipment that is possible, the figures perforce are neither the minimum requirements nor the maximum for units presently in operation. As an example, during the 1949-50 processing season Minute Maid Corporation had one of its various plants equipped with only refrigeration units and another with only steam units. The first plant had a rated capacity of 22,000 pounds per hour of evaporation, while the second had a rating of 17,400 pounds per hour. For the concentrating units in the 22,000 pound plant, the steam and power demands were 1,000 pounds per hour and 730 kw., while for the other plant the steam demand was 18,000 pounds per hour and the power requirement 67 kw. If these figures are converted to an equivalent basis the ratios for the utility demands were 22 to 1 for steam and 0.12 to 1 for power or the same order of magnitude as those shown in the table. The water requirements also coincided generally with those previously indicated.

TABLE 1

Utility requirements for double-effect units of 10,000 pounds water/hour evaporating capacity

Unit	Steam	Water	Power	Waste streams
	Lbs./hr. at 125 p.s.i.g.	Gal./min. 80° F. (26.5° C.)	kw.	Gal./min.
Refrigeration cycle [b]	492	250	320 [c]	20
Steam recompression [b]	7500	1000	20	1020
Ratio of steam system to refrigeration system	15.1	4	0.06	51

[b] The figures have been taken from various manufacturers' bids.
[c] Includes 400 HP compressor.

The operating cost for utilities alone can be calculated from the table. If costs of $0.60/1000 pounds of steam, $0.01/1000 gallons of water, and $0.012/kw. hour are assumed, a saving of about $0.003 per gallon of concentrate is indicated by use of the refrigeration unit. In a season in which 1,000,000 gallons of 42° Brix concentrate were produced, the saving between the two systems would amount to $3,000.00. The saving favors the refrigeration system, but this unit (installed complete) will cost approximately $30,000.00 more than a similar steam unit. Under these conditions the pay-off period is objectionably long. However, if only the above figures are examined an erroneous picture will be obtained. The low-temperature evaporator is a part of a plant and must be integrated into the process. For example, many food plants have by-product operations requiring sizable amounts of low-pressure steam. In these cases, careful study should be made of steam-driven generator or compressor equipment as opposed to steam ejectors.

In Table 1, the waste streams are considered to be those which may be difficult to handle, either because stream pollution may occur or because the volume of the waste is large. Therefore, the barometric condenser water from the steam unit may in certain cases create a problem. In the refrigeration system the only objectionable stream is the condensate, which generally contains volatile organic compounds. Certainly the cost and

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951.

manner of handling the waste streams should be investigated before selecting one unit over another.

In the last few years, owners of low-temperature evaporators have been handling an increasingly wide range of products. Many of these do not require the extremely low temperatures that orange juice does. For these materials, an evaporator which can operate with product temperatures from 75° F. (24° C.) to as high as 130° F. (54.5° C.) would be desirable. The steam recompression unit can be readily converted for this type of service. If proper consideration is given during the design stages, the refrigeration unit can also be converted; although there may be more time and expense involved than with the steam system.

If insurance against internal or external collapse is to be carried on the evaporator, the design should comply with the ASME Code for Unfired Pressure Vessels. The problems involved in designing sections containing ammonia or steam have been recognized and overcome but the upper and lower evaporator heads and separators, which are essentially vacuum envelopes, have in some cases been too light. The latest evaporators, however, have been properly designed.

OPERATING CONSIDERATIONS

Assuming equal care in operation, all properly designed evaporators will turn out a high-quality product. Due to its lower temperatures and shorter transit time, the single-effect single-pass evaporator retains more of the volatile components. A single-effect system can be put on the line merely by admitting fresh juice and working it through the unit as rapidly as possible. Shutting down is equally simple in that the fluid is worked through until the unit is pumped empty. In contrast, a double-effect unit will not operate satisfactorily until material is circulating in both effects. It is possible, of course, to circulate water in one effect until product can be pumped over from the other, but in practice this does not appear to be worthwhile. Therefore, in starting a double-effect unit, material is fed to both effects simultaneously and circulated until normal operating concentrations are attained. In order to shut down, the material in both effects must be brought to the final concentration. This is done by reducing the level in the low Brix effect to the minimum operating point and pumping back and forth between the two effects until the material in both effects is either the same or of such concentration that the mixture of the two gives the desired product Brix.

The steam systems require a reliable steam supply. They are particularly sensitive to pressure fluctuation and to wet steam. Venting of non-condensables is of paramount importance, since air-binding will unbalance the entire operation. A serious upset in the steam or barometric condenser water supply may cause the steam ejectors to "break." When this happens, steam flows back into the evaporators with the possibility of loss of product. The plant should be so designed that the steam and water supplies are independent of the power supply so that, in the event of a power failure, the evaporators can be removed from the line in an orderly manner.

The refrigeration compressor requires a reliable source of energy for the compressor drive. Noncondensables must be removed from both the evaporator vapor side and the vapor spaces of the ammonia vessels, but in practice this has proved to be a lesser problem than with the steam units. A more serious consideration is the removal of oil from the low side of the refrigeration system which, if allowed to build up, reduces the heat transfer coefficients and may interfere with the proper circulation of the refrigerant. If the compressor stops for any reason, the unit, as a whole, goes down. One definite advantage is that there can be no entry of steam or other foreign material into the evaporators, since there is no reversal of vapor flow. Furthermore, the evaporators are protected from blow-back from the air ejectors by the water vapor condenser. In plants in which both types of units are installed, the operating crews show a slight preference for the refrigeration system.

INSTRUMENTATION

The trend in the citrus juice concentrate industry has been to instrument the units so that only very slight supervision is required. A complete set of instruments for an evaporator will cost around $4,000.00 and will include temperature, level, and Brix control. At the present stage of development the principal difficulty appears to be that the instruments sometimes work against each other. Although Brix control units measure density, they generally control it by admitting to the final effect low density material from elsewhere in the system. Sometimes the control may be obtained by changing the rate at which the product is pumped from the evaporator. Either of these methods affects the level, and the Brix controller action may cause a raising or lowering of level when the level control is trying to effect the opposite action. Since in most cases it is desirable to operate the evaporators with minimum levels, the level controller has a rather small range in which to operate. Perhaps a more useful type of Brix control would be one which controlled Brix independently of level by altering heat input or some other variable, but such a system has not been perfected as yet. There are two types of Brix control instruments in general use. One measures the density of the juice; the other measures the boiling-point-rise of the material being evaporated. The density device is more accurate and reliable but it is also more expensive; and, since most plants have a second density adjustment prior to packing, the boiling-point-rise controller will usually prove to be the more sensible choice.

SANITATION

As with any food-handling equipment, low-temperature evaporators should be free of pockets, crevices, or other points which will retain material. The unit must also be completely accessible for cleaning and inspection. A well-designed evaporator will allow operation on citrus juices for periods of as long as 130 hours with no significant increase in bacterial count. However, the evaporator will not correct poor housekeeping in other parts of the process, and the general performance of the unit depends on the vigilance and ability of the operating and quality control groups.

When processing sound fruit, counts of 5,000 microorganisms per cc. or lower are obtainable. Conversely, use of soft fruit or a poor sanitation program will cause counts to increase to a point where cleaning every 72 hours, or more often, is necessary.

The principal trouble-points on sanitation are those which are not continuously washed by the circulating juice. Such points are the upper and lower chambers of the evaporators, the sides and domes of the separators, dead-end pockets in piping, and the interconnecting vapor piping. At these locations entrained particles or spattered liquid may coat the surfaces and provide an ideal medium for growth of yeast, mold, or bacteria. Areas such as the above should be so designed that they are either washed continuously or they should not be washed at all. The worst feature is to have areas at which sufficient build-up occurs as to cause drippage into the product-stream.

Another serious cause of contamination is a periodic rise and fall of the levels in the evaporators. These may occur over many hours and if the rising level washes areas that have been exposed for sufficient lengths of time, the bacterial count may show a sharp increase. Sanitary design is basic to all food processing and it has been developed over many years. However, the translation of these principles to equipment in which the separator chambers are 10 feet in diameter and the vapor piping 42 inches (or better), is by no means simple. The suction throats of the large steam ejectors are often the source of both organic and inorganic contamination. Small amounts of scale and other debris tend to collect at these points and if the booster stalls this material is often blown back into the product.

Citrus juices contain hesperidin and other sparingly soluble components which precipitate on the tubes of the evaporator. Such deposits interfere seriously with heat transfer and, over a period of 72 hours, enough may collect to reduce the capacity of the unit by 25%. This reduction can be overcome by increasing the temperature of the heating medium, a method which has definite limitations and which is not too desirable from a quality standpoint.

The answer to sanitation problems is to have a well-organized sanitation program which is closely supervised. Since it costs between $200.00 and $300.00 to clean a medium-size plant not including lost production time, management must be thoroughly cognizant of the importance of sanitation. Most plants use a combination of chlorinated water rinses, detergent, and germicidal washes. All pockets are examined and hand-scrubbed if necessary, the evaporator heads are opened, and the distributing baffles cleaned. In some cases it may be necessary for personnel to enter the lower evaporator chambers for more thorough cleaning.

CHOICE OF AN EVAPORATOR

In the spring of 1950, Minute Maid Corporation decided to increase the concentrating capacity at its plant in Leesburg, Florida. At that time the installation consisted of three 5,800 pounds per hour evaporators of the double-effect steam recompression type. There was also a modern 42,000 pounds per hour boiler generating at 250 p.s.i.g., a cattle feed mill, and a molasses plant. Naturally it was desirable to use available plant utilities to best advantage and to purchase increased capacity for a minimum capital expenditure.

For reasons of economy, only double-effect evaporators were considered. The fruit handling facilities dictated that a unit of approximately 6,000 pounds per hour evaporating capacity would be the proper choice. The steam load on the boiler was 27,500 pounds per hour, exclusive of the molasses plant load, which was 14,200 pounds per hour at 10 p.s.i.g. If a steam recompression unit were chosen, the steam demand would be increased by at least 5,000 pounds per hour, which would have required use of an old low-pressure boiler. To reach an intelligent conclusion, an economic study was made of eight combinations. Included in this list were the steam recompression unit, motor and steam-driven reciprocating, and centrifugal compressors. In those cases where motor-driven compressors were considered, a steam turbine-driven electrical generator was included to provide steam for the molasses plant. It would, of course, have been possible to install a motor-driven compressor system and blow down steam from 250 p.s.i.g. to 10 p.s.i.g. for the molasses plant, but this alternate did not appear capable of sufficient return to be attractive.

The economic study indicated that an ammonia refrigeration system with a motor-driven reciprocating compressor in combination with the turbo-generator was the best choice. This installation cost approximately $26,000.00 more than the steam recompression system but was capable of saving $11,000.00 per year in operating costs. The reason that the capital investment difference was so small was that additional cooling-water facilities would have been required had the steam system been installed. The turbo-generator system had other advantages. It provided great flexibility in that it could be run on the same schedule as the molasses plant, whereas a turbine-driven compressor would provide steam and useful work only when the concentrator was operating. The concentrating and molasses plant schedules do not dovetail, since the molasses plant receives presswater from outside sources. The generator could be located next to the molasses plant, while the compressor would have been in the concentrator area some distance away.

The flow sheet for the concentrating unit is shown in Figure 1. It is a conventional double-effect unit with backward feed. The first-effect is heated by warm water which, in turn, receives heat from the ammonia condenser. The water vapor is condensed in an inclined shell and tube vessel with the ammonia inside the tubes. It is believed that this inclined water vapor condenser is the first installation of its kind in the low-temperature evaporator field.

The bids on the evaporator bodies and accessories varied from 1.36 pounds of water evaporated per square foot for the refrigeration system to 2.50 pounds per square foot for the steam system. The spread in cost, however, was only $41,000.00 for the steam unit to $49,000.00 for the refrigeration type. The refrigeration systems, themselves, varied from a low of $26,000.00 for the reciprocating compressor and its auxiliaries to $42,000.00 for one of the centrifugal compressor systems.

The system finally selected contained 1,750 square feet of heating surface in the first effect and 2,100 square feet in the second. The heat transfer coefficients were 75 and 117 Btu. per hour/square foot/degree F., respectively. The compressor was a horizontal 2-cylinder double-acting 9¼ x 12 inch machine driven by a 200 HP motor. In production (1951) of orange juice the system has evaporated 6,600 pounds per hour of water and the heat transfer coefficients have been 83 Btu. per hour/square foot/degree F. for the first effect and 137 for the second. The discrepancy between the design and actual coefficients is caused by a variation in the viscosity of orange juice, which may vary as much as 50% from year to year.

Figure 2 is a photograph of the unit, which has been installed outdoors, the general trend in the last three years. The first effect is nearest the camera.

In the foreground is the water circulating pump with its discharge piping connected to the ammonia con-

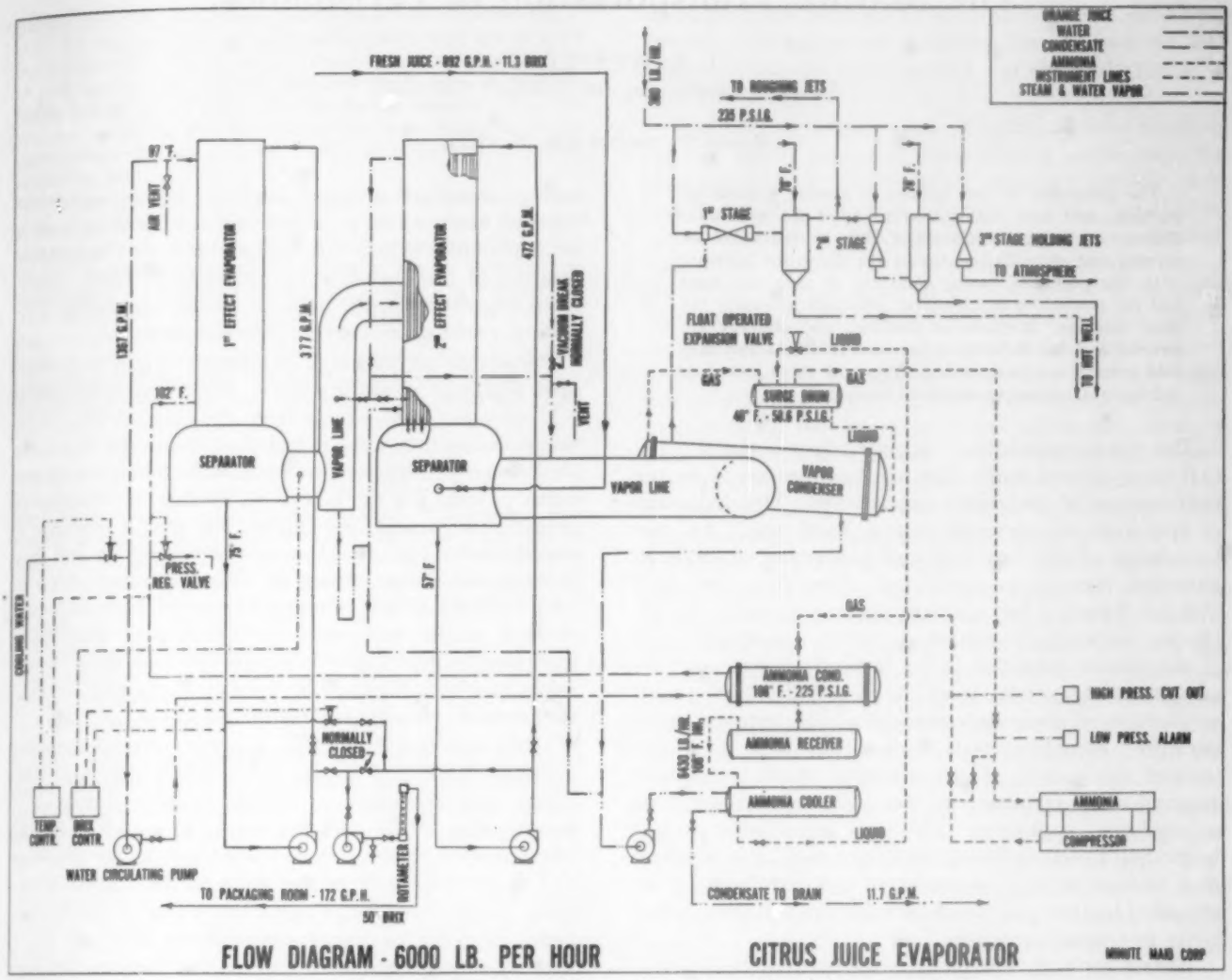

FIGURE 1. Flow diagram for a 6,000 pounds per hour citrus juice evaporator.

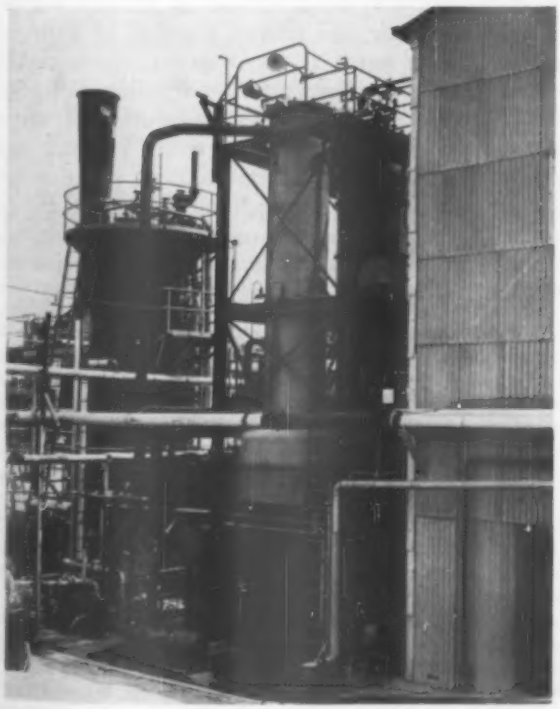

FIGURE 2. A 6,000 pounds-per-hour evaporator.

denser. Above the ammonia condenser is the water vapor condenser, and below it is the ammonia receiver.

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The Marine Transportation of Perishables[a]

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The influences of the factors of source, processing, packing, and land transportation upon the successful delivery of cargo are discussed. The procedure of receiving and shipside inspection are described together with the problems facing terminal or ship operators and the protective or corrective measures necessary for their solution. Methods of handling and stowage are covered and the differences between shoreside and ship cold storage are pointed out. Types of ships and their refrigerator arrangements are touched upon.

The word "perishables" is generally associated with that class of food-stuffs that are best preserved by an environment of controlled atmospheres. The definition of the word is currently not a fixed one. As our knowledge of the behavior and properties of foods is extended through research and observation, we find that the definition becomes broader and broader. As we become increasingly critical of quality, appearance, and of nutritional values of foods, it becomes necessary to adjust the scope of the term. We are daily making new application of controlled atmospheres in terms of temperature, humidity, and composition, and we have learned that many of the so-called stable foodstuffs respond very favorably to the technique of specified atmospheric conditions. The food technologist would be the first to tell us that all foods are perishable whether they be fresh, frozen, or processed and that they may be classified by their degree of perishability and their sensitivity to critical exposures.

Nature produces our foods in the fields or in the flesh and in most cases she is aided by the artifices of man. Usually, the producer strives to match climatic requirements and to provide environments conducive to the development of produce the characteristics of which are such that they will meet a ready and profitable market. At times there is marginal production in terms of climate or soil chemistry, and occasionally the better methods of processing and handling are compromised. It is not unusual that seasonal or weather conditions are detrimental and there are occasions when the producer is inclined to stretch either end of the harvest season beyond elastic limits. There is always the ideal in environment and method to be found but the optimum for growing things is of momentary attainment and the major portion of the production must come in some degree of compromise with perfection.

The proximity to the ideal in all factors of production and processing is reflected in the storage and marketing life of any perishable, and in as much as transportation to storage or to distribution is a part of this post-harvest life, all transportation agencies are involved and concerned. Land transport is of relative short duration, but it is often short of perfection and can have telling effect upon subsequent storage life. Generally speaking, marine transport succeeds land movement, and while the near ideal can be provided by mechanical equipment on shipboard, the ship can be placed in a very vulnerable position of responsibility for unfavorable latent conditions originating in the field, or during harvesting, producing, packing, storage, and land transport.

Perishable cargoes may have their origin in a hundred scattered producing areas; they may originate in cold storage plants remote from the ship's berth, or on rare occasion they may be transferred into the ship from a tidewater refrigerated terminal. The refrigerated terminal is ideal for the assembly, storage, or transfer of perishables intended for export, but such a terminal is unsuitable for any other type of cargo handling and they pre-suppose the servicing of all-refrigerated ships of which there are few. Products received from any cold storage source and intended for export may have expended much of their storage life and their breakdown may be accelerated by the exposures and handling incidental to transfer for marine shipment.

If the movement of cargo was only that of shipping a single commodity destined to a single port and consignee, the operation would be happily simple—and newsworthy. This performance is approached in the movement of bananas from Latin America or of citrus and apple cargoes from the West to the United Kingdom, but the more usual operation is that of the complicated handling of many commodities destined for a number of ports and for countless distributors. To load a heterogeneous cargo into a ship in such a sequence that each item will be accessible at its destined port and stowed in safe and proper manner, or segregated according to temperature requirements, the complicity becomes apparent. The perfect scheduling of truck or rail car arrivals from numberless sources of varying distances is something only striven for but never attained. The demurrage of rail cars, the pier exposures of waiting cargoes are not desirable conditions and only alert and keen personnel can minimize them. Obviously the cooperation of the shipper and land transportation agencies is essential to good operation.

A ship whose refrigerating equipment may be ideal and whose operation may be perfection cannot make good delivery of originally imperfect produce. In the transportation of fresh fruits and vegetables there are many factors that can nullify the best of equipment and operations. The shipment of immature or overmature products, the imperfections caused by field diseases, by rough handling in the field during packing and trucking can cause incipient damage that may progress enroute while the product is at the most vulnerable and critical period of its post-harvest life. Pre-cooling of fresh products is the exception rather than the rule and the removal of respiratory heat from the tightly-packed container is difficult and slow. It is rather surprising to find the widespread belief among laymen that once the product is placed within an air-cooled room, the maturing processes are entirely arrested. And too often the pre-cooling of fresh products, when done, is but a gesture rather than a thoroughly penetrating operation. It is understandable

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that the producer should wish to hold back prime quality perishables for long storage and post-season marketing, but it is of equal importance that produce intended for export should be of such quality that it will withstand the rigors of multiple handlings and unfavorable exposures during transfer. The ship operator should be able to assume that he is receiving in his care products that are of good quality, of proper maturity, and suitably packed.

It is the ship operator's belief that the weakest link in our chain of distribution of perishables is that of land transport between packing plant or cold storage and the ship's side. Freshly harvested and packed produce is always prepared remotely from the marine terminal and it must be delivered by truck or rail car. For the so-called chill product the rail car does a creditable job, but often the truck transport is not above criticism. As of today much fresh produce is hauled for long distances without benefit of refrigeration, without adequate cover and exposed to the elements. Too often the refrigerated truck does not function satisfactorily. At times the truck driver and sometimes even the truck owner have little appreciation or understanding of the importance of the refrigeration machinery and all degrees of disrepair are often in evidence. It should be to the interests of the manufacturer of truck refrigerating machinery to campaign for adequate servicing of the equipment he sells. For the purpose of saving weight or space, the insulation of the refrigerated truck is not always as efficient as it should be, and there are times when one ponders over the relative size of truck and refrigerating machine.

The shipping of frozen foods by car or truck is subject to continuous improvement. Mechanical refrigeration of rail cars is now going through an intensified period of experimentation in response to the demands for better temperature conditions for quick-freeze products enroute. With the maximum of 30% salt and ice mixtures in the bunkers of the conventional car, initial lading temperatures of twelve degrees above zero have been attained, but summer top-tier temperatures at distant delivery are far from ideal for this class of food. The usual temperature variations during delays and icing stops would not be tolerated in warehouse or aboard ship. The loading of sub-zero products in a conventional rail car calls for a period of self-refrigeration by the product until equilibrium is attained and the brine becomes capable of absorbing the heat of leakage. The author has projected car construction in which the heat of leakage is intercepted at a temperature level which the salt and ice mixture is capable of maintaining. By the proposed method the initial state of refrigeration of the frozen goods is supported and it is anticipated that temperatures satisfactory in level and constancy will be had until distant delivery. There is little than can go wrong with a piece of ice, even when unattended between servicing stations. With the use of the presently available rail cars, frozen foods are often received at the ship's side at temperature levels considered unsuitable for this class of goods.

It is not unusual to see frozen foods arriving at the ship's side in trucks having no refrigerating machinery attached and sometimes even uninsulated trucks are used. With the usual short haul between the cold storage plant and the ship and the still common lack of appreciation of the care that frozen foods should have, there is a tendency to gamble leaving little margin in time or reserve refrigeration to meet possible traffic delays or pier storage. With the refrigerated truck's refrigerating machinery often in anything but prime condition one might almost suspect that the equipment is adding heat rather than performing its function of intercepting heat of leakage.

The practice of top-icing of un-precooled produce in land transportation is a matter that should have further research. The congealing of crushed ice into a snow blanket is certainly a barrier to convective air circulation within the enclosure and surprising observations of temperature and ineffectiveness have been made.

The influences of land transport and their shortcomings are not displayed here to make averse comparisons but they are reviewed to show their relationship and importance to subsequent marine carriage. Obviously, there are some satisfactory loads delivered to the ships, but the weaknesses are displayed here to indicate that there is room for improvement and that cooperation is earnestly invited.

When the perishable cargo is unloaded from truck or rail car and is landed at point of rest of the pier, the responsibility of the terminal operator or the ship begins. While the ship operator should be able to assume that all products given to his care are of prime quality and condition, yet he finds it to the interests of the shipper and consignee as well as himself to maintain a watchful eye for irregularities. The carrier has not the right nor the ability to open each individual container to make a total inspection, but a superficial examination of each load will often disclose that there are conditions that do not augur well for satisfactory delivery from the ship at destination. The conditions may represent advanced maturity, plant disease effects, or improper exposure between production and receipt. They may represent mechanical damage to the contents or an unsuitable or too fragile container. Frozen foods may arrive in thawed condition. Frequently the shipper or broker has placed his order by wire or telephone and he has not seen his shipment. It is usual that when discoveries of unsatisfactory conditions are reported to the shipper corrections are graciously made, or that the bill-of-lading protest can be made without offense. At the same time the ship is properly protected and absolved if failures in delivery develop from such defects. This procedure of superficial examinations was instituted in San Francisco by the Matson Navigation Company several years ago and the results have been most gratfying. The practice has had some far-reaching effects. It has alerted shippers into shipping highest quality merchandise; it has resulted in better packaging, improved care in handling, and claims have entirely disappeared.

The terminal operator and the ship owner have full appreciation of the detrimental effect of avoidable delays in loading cargo into the ship's refrigerators and they strive to get it under refrigeration with utmost dispatch. They are limited by the sequence of delivery of the cargo to the pier and sometimes by the cargo loading plan which requires the early loading of heavy or sturdily packaged products over which the light and fragile containers must be stowed. The sequence of loading is regulated by the routing of the ships to ports of call, by segregations of temperature requirements, and by the accessibility of the refrigerated spaces. There are conditions beyond their control relative to speed of loading cargo, for example, in response to our new way of life, waterfront workers will not work in a refrigerator in which the cooling apparatus is in operation.

As before stated, there are conditions relative to marine transportation of perishables which are peculiar to the industry. They are not only in matters of operation but they involve ship design. There are, generally speaking, two types of vessels that carry refrigerated cargo, they being the all-refrigerated ship and the combination vessel which carries both refrigerated and general cargoes. (See Figures 1 and 2). The choice of arrangement is usually dictated by the trade in which

FIGURE 1. Lower hold of an all-refrigerated vessel. (British). Note cold air inlets along base and return air trunks overhead.

the vessel is engaged, but the trend has been toward a design in which there are a goodly number of refrigerators of relatively small volumes in a combination vessel. This type is particularly suitable in a trade which is served by vessels in frequent sailings and which can supply perishables to direct marketing. The alternate plan of the all-refrigerated ship is more suitable to services of infrequent sailings where hold-over storage is maintained at the port of discharge, or for military and specialized services.

The all-refrigerated ship has some short-comings in general merchant trade. Unlike cold storage houses ashore, the marine counterpart is not fitted with vestibules, corridors, or elevators. Nor do such accesses conform to the well established and efficient methods of handling cargoes. Consequently the all-refrigerated ship has large volume compartments open to the weather without benefit of refrigeration for long periods of time during loading and discharging. During the loading of fresh products there is little means for the escape of field or respiratory heat until the entire space is loaded, the compartment closed and the refrigeration apparatus placed into service. By the same token, during discharge there are portions of the load that will be without active refrigeration until the unloading operation is completed. The conditions are not ideal for frozen foods. In addition, the lower holds are usually of deep dimension and there are practical limits in heights to which fragile products or containers can be piled.

It is obvious that the multiple room arrangement is superior in providing proper protection of the cargo during all operations, although it results in high costs of construction and in large losses of revenue space to insulation, equipment, and accesses. To meet structural and operating conditions the multiple room plan will locate the compartments in the upper levels of the ship. In a vessel carrying both refrigerated and general cargoes, it is good design to so place the refrigerators that the perishables may be the last cargo loaded and the first discharged. Being subject to design conditions relative to the ship's standing position afloat, or its trim, the refrigerated cargo which is usually of less density than general cargo, would be carried near the mid-length of the ship. In terms of stability of the ship when loaded, it would call for the installation to be made high in the vessel. To favor loading conditions the refrigerators are almost always arranged symmetrically about the vessel's longitudinal centerline.

Structural limitations would give a between deck height of approximately ten feet in the steel and the finished refrigerator would have a ceiling height of about eight feet (Figures 3 and 4). The thwartship dimension of the compartments abreast the hatches is limited to the ship's side on one hand and by an allowable working area along the hatches on the other hand. The floodibility subdivision of the vessel affected by a calculated spacing of the ship's watertight bulkheads limits the longitudinal dimension. These dimensions are in contrast with those of the more familiar shoreside cold storage plant. The relationship between room floor areas and ceiling heights has much to do with the methods of applying refrigeration to the compartments.

The maritime business is an enigma. There is perhaps no other industry that has had such an empirical beginning, had a more scientific development nor one that is more dominated by practical considerations. Shipping is steeped in tradition, and tradition is good as long as it becomes the motive power instead of the mooring. Mechanical refrigeration as we know it in universal service today had its beginning aboard ship, but this branch of the marine industry was apparently weighted with the mooring type of tradition and lost its leadership to the stationary industries. After shedding the dense air refrigerating machine, it held on tenaciously to the carbon dioxide and ammonia systems, while at the same time the shoreside applications experienced a more scientific and rapid development.

The discovery of the non-toxic Freon refrigerants and the availability of the high speed, space saving, weight saving machinery associated with them has given new impetus to the development in marine applications, and

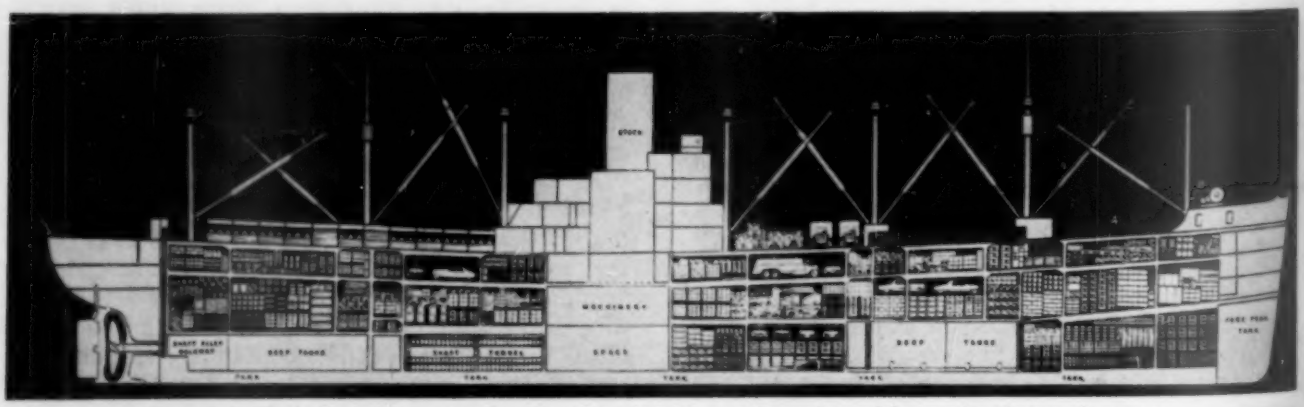

FIGURE 2. Typical arrangements of an American freight vessel carrying refrigerated and general cargoes.

FIGURE 3. 'Tween deck refrigerated compartment with hatches closed. (Photo courtesy of Moore Drydock Co., Oakland, California.)

FIGURE 4. 'Tween deck refrigerator fitted with rails for unfrozen meat in a multiple-compartmented vessel.

the hazards of war have made the use of these refrigerants all but imperative. Aside from the general adoption of the Freons, marine refrigeration can point with little pride to its engineering progress in our recent shipbuilding program. On the debit side, distribution of refrigeration by calcium chloride brine was discontinued and the short-comings of direct expansion systems have been emphatically impressed upon the ship owner who has fallen heir to the vessels so equipped. Private ship owners, however, have made some real contributions to the art since the war's end.

Early ship applications employed wall coils for the distribution of refrigeration, but large compartments met with limitations in this respect and ceiling coils were added. Due to defrosting troubles during loading and discharging, the ceiling coils were acknowledged cargo spoilers and they were generally discarded when substitute methods were developed. However, at the risk of being called oldfangled, we must admit that there are certain qualified advantages of wall coils in the small room. The larger refrigerators require more active movement of chilled air to approach uniformity of conditions necessary to good refrigerating practice and this has been quite satisfactorily met by the ported false bulkhead cold air systems typical of the banana carrying ship, or by the use of the diffuser type cold air unit fitted with distributing ducts.

The transfer of heat from the product to the refrigerating surfaces must be effected by a stream of air acting as a conveyor and this moving air must contact each element of the cargo in as uniform a manner as possible. With the characteristic low specific heat and low specific weight of air, relatively large volumes must be moved and this requires considered planned in ship applications lest it resolve itself into unsuitably high velocities. The dehydrating effect of high velocity air is well known, hence broad streams of low velocity are preferable to narrow streams of high velocity. These conditions give merit to the false bulkhead cold air systems of good design for large area compartments, as well as the shielded wall coil system fitted with recirculating fans for the small room. The cold air units have been generally used in the newer installations and we must admit that with scientifically planned stowage, good results have been attained even though they may not inherently provide the ideal of uniform conditions in the tightly stowed refrigerator.

It is obvious that with all types of applications, the return air paths are more vitally important to the refrigeration of cargo than is the mechanical system that distributes the air to the compartment. It is imperative that the air streams be properly directed through a permeably stowed cargo rather than to permit the same to by-pass around a tightly stacked load. This application has been the subject of much study by the author and his theories have been amply proven in practice. The study has shown that the disregard of these findings can be costly in terms of unsatisfactory delivery of perishable goods.

The question arises, "Wherein do marine operations differ from those established for shoreside cold storage warehouses?" They differ most importantly in the manner in which the compartments are loaded and in the consequent methods of operation. The high ceilings, the open passageways, the wall and ceiling clearances so common to the warehouse are not to be found in the ship's refrigerators. The volumes within the ship's enclosure are of high cost and every cubic foot of space must be made available for carriage of revenue cargo. It is in part an economic problem and could be likened to that which would be forced upon a cold storage plant operating competitively were it to be located in the financial district of Manhattan Island. Secondly, the loaded cargo must be so stowed that the stacks will remain secure and stable if the vessel were to be tossed about by heavy seas. The walls may be called upon to bear heavy loads and wall clearances or passageways will not meet these conditions. In consequence the average ship's refrigerators will be totally filled and if the loads are properly stowed, full consideration will be given to each type of refrigeration system to so arrange the air channels within the stacks as to permit the air streams to do their work. Until this new concept was applied, rule of thumb methods prevailed and there was little to differentiate between the stowage of perishable cargoes from that of general cargo. Had these considerations been observed during the late war period, we would have heard less of the need for conservation of overseas foods.

Considering the inevitable delays and exposures between the sources of the perishables and the ship's refrigerators, there are many things that can be done in cooperation by the producer and processor that will enhance the chances for good delivery of his shipments.

Whenever possible the frozen foods should be sub-cooled to permit some temperature rise during transfer without approach to thawing. Thorough pre-cooling of most fresh products is highly desirable to carry them through transfer and the earlier to establish suitable conditions within the ship's compartments.

Some items however, can suffer by being pre-cooled to too low a temperature. Deciduous fruits such as cherries, plums, and grapes if cooled below the dew points at transfer, will sweat excessively and develop conditions conducive to the formation of mold or of early break-down. Shell eggs usually originate in cold storage warehouse chambers and will generally sweat during loading and during discharge. Eggs, like the deciduous fruits, should be removed with greatest dispatch to the drying atmosphere of the cold storage room or to direct market.

Leafy vegetables should be precooled before packing to remove field and respiratory heat while the individual unit can be adequately cooled. Exception may be made in the penetrating pre-cooling process being established in the California lettuce industry in which the head is refrigerated by the evaporation of included water while under a high vacuum, the state temperature of water under these conditions being attained. There is a growing use of film bags for the packing of many fresh products which, while retarding direct refrigeration, will maintain desirable degrees of humidity and prevent excessive losses through dehydration. Precooling of products thus packed should take place before being enclosed to minimize the condensation of moisture on the inner walls of the bags. This moisture does not add to the sales appeal of some perishables.

The practice of packing ice within a crate has its limitations as well as its merits. Corn, cauliflower, broccoli, and carrots respond well to ice packing within a moisture-proof paper liner, the melting providing improved temperature levels during transfer and good humidity conditions at all times. Export lettuce, however, should never be so packed as the ice causes bruising and injury and the excess water that comes with the ice's melting develops conditions conducive to bacterial breakdown of the delicate leaves.

Frozen foods should be packed in cartons made of water-repellant paper to resist damage by condensation during transfer. Soft absorbent paper stock is usually a good insulator and the atmospheric moisture will not collect as frost but as free water. The carton will thus lose its strength by wetting and it will not support its load when stacked in the ship. It may also give trouble by freezing to its neighbor when refrigeration is applied.

The shipment of fabricated meats is becoming more popular and is the usual method of shipping military meat supplies. These packages usually bulge from expansion through freezing and if the bulges are on two faces only, they will stow satisfactorily and provide good air channels, but if the package bulges on all faces as it sometimes does, it makes for very unstable piling. Anything can happen in a seaway, and usually does. Cartons intended to carry any refrigerated product should be assembled or taped with water-proof glues to prevent loss of the glue's adhesive properties and the collapse of the container when moistened by condensation during transfer. Most packers reinforce their cartons with wire or steel straps which is good insurance against losses of this kind. Boxes made of single-ply veneer wood are generally satisfactory for unfrozen products, but are most undesirable for frozen fabricated meat. In the latter case a few handlings will reduce them to wire-bound bundles of kindling and the products made subject to unsanitary exposures. Good packing for any type of product intended for export is costly and in the highly competitive business of distributing perishables, there is an inclination to reduce production costs at the expense of secure packing. The enhancement of sales appeal should well cover the added costs of improved packing.

The shipping of properly selected produce in well designed containers will make for orderly, secure stowage to which refrigeration can be confidently applied. By carefully studied procedure in stowing, the heat can be removed from the load in a degree of uniformity that will assure satisfactory delivery of good products at destination. The moving of refrigerated air through the load must be accompanied by a rise in the air temperature, and when produce has not been pre-cooled, the temperature rise will be of considerable magnitude until equilibrium is established. These products nearest the point of entry of the air will be the first to receive the benefit of cooling and each successive package will be effectively cooled in its turn. Care must be exercised in the stowage of certain perishables to prevent their damage by the dehydrating effect of high velocity air streams.

Temperature readings made in a shoreside warehouse room represent approximately uniform conditions within that space. Because of the described conditions within a ship's refrigerators, we cannot assume that, initially at least, a temperature reading in these spaces is altogether representative. With cold air systems, great care is observed not to admit air below the freezing temperature of the cargo carried because of the absence of a large diffusing zone over the load. For a given compartment then, we have a limit to the rapidity in which the heat can be extracted from the cargo. When cold air systems are employed aboard ship, the room temperature is assumed to be that of the return air entering the cold air unit. In rooms fitted with wall coils, caution is also taken in the method of stowage and in the selection of cargo to be placed at the foot of the coils to prevent damage by freezing. Wide spacing for air channels should be provided to prevent the impounding of low temperature air at the coil bases and hardy products of low freezing temperature should be selected to occupy this zone. The room temperature of the wall-coiled compartment is assumed to be that at the ceiling in the geometric center of the space. Good refrigeration design will provide for the equivalent removal of initial heats within seventy-two hours, but the afore mentioned practical limitations will always govern.

Rooms carrying a single commodity would carry temperatures approaching that prescribed by good warehouse practices and as recommended by the American Society of Refrigerating Engineers, but with the usual heterogenous cargo carried many compromises with the ideal must be made. Fortunately, most fresh products respond to a common temperature approaching 32° F. (0° C.), while their freezing temperatures are below that level. The generally accepted compromise is in the range of 34° to 36° F. (1° to 2° C.) and with a minimum of variation. This being the outlet or return air temperatures, the inlet air closely approaches the ideal. In a separate class are fruits such as bananas, pineapples, and papayas grown in the tropics which require much higher temperatures inasmuch as the chilling of these products will interrupt their ripening processes after removal from refrigeration. In this regard it may be pointed out that the University of Hawaii and the Matson Navigation Company have collaborated in extensive practical tests on the carriage of these perishables. With the wide and sometimes abrupt variation of climatic conditions to which the moving ship is subject, a close watch is maintained upon all temperature readings. The most reliable and accurate readings are made from the electric resistance type of instrument and no cargo carrying refrigerator is complete without a recording thermometer.

In the matter of humidity control, it is quite impossible to simulate conditions striven for in shoreside warehouse practices. We may question the accuracy of relative humidity readings at low temperature in a warehouse, or that the readings are representative of absolute uniformity of conditions within such a room, yet the attainment of desirable humidities is within the realm of possibility due to the long periods of refrigeration and the isolation from outside influences. The same procedure might be approximated in a vessel carrying precooled loads in long voyage, but with the usual practice of carrying un-precooled cargoes of fresh products and the short voyage periods of our modern fast ships, we find that the trip is generally nearing completion before humidity equilibrium can be attained. Generally speaking, the humidity conditions within a ship's refrigerator are volunteer and the principal means of

control are provided by a minimum split between refrigerant and room temperatures, and by the practice of operating the recirculating fans at their lowest practical speeds and capacities.

Humidity conditions may be influenced by the addition of replacement air to the compartment, but in general this operation is not undertaken for that purpose. When homogeneous cargoes such as bananas or citrus fruits are carried and there is a build-up of undesirable volatiles from respiratory processes, a measured amount of air is admitted to the inlet side of the cooling unit. Various methods of determining the concentration of these volatiles have been devised and the readings may be used to regulate the admittance of new air. More generally, replacement air is admitted by practical rather than scientific considerations. However, in most applications the voyage periods are short enough that the benefits of adding air are outweighed by other considerations and the practice is omitted.

We have seen the concept of the so-called freezer service change in rapid order in the marine application. The 16° F. (—9° C.) freezer of twenty years ago changed to 10° F. (—12° C.) at the beginning of the late war and to 0° F. (—18° C.) toward the end of that period. Traditionally, the ship is not called upon to freeze cargoes but merely to maintain proper environment for pre-frozen goods. Under the demands of shippers of frozen foods, particularly those popularly known as quick-freeze products, a few ship owners have provided facilities to maintain —10° F. (—23° C.) and any or all compartments capable of carrying any temperature from —10° F. to ambient levels. While —10° F. is lower than ordinary storage requires, it provides a reserve degree of refrigeration to carry these products through exposures incidental to transfer from the ship.

For relatively long voyages, certain classes of perishables have been carried without benefit of refrigeration. This service which provides lower freight rates and is known as ventilated cargo, has appealed to the gambler who is willing to assume his own losses, and he has had sufficient success to make the operation a well established procedure. Rugged items such as potatoes and onions have been successfully carried for long voyages. During the war when refrigerated space was limited and the South Seas military demands were heavy, large consignments of eggs intended for early consumption were carried through the tropics under ventilation with surprising success. The carriage of ventilated cargo requires the movement of large volumes of air to carry off the quantities of heat and respiratory products, the generation of which are accelerated by the higher temperatures.

The interests of the American food technologist now exceed the boundaries of his homeland. Since our nation has assumed the humanitarian and political responsibility of husbanding the free world, the conservation of our food supplies has become second only in importance to its production. It is fitting that the maritime industry which transports the food should join forces with the technologists who produce them and direct their efficient use.

Upon a common ground of understanding of each other's operations and problems, both groups can more effectively accomplish their missions. The contents of these pages are the evidence that the American shipowner is ready, willing and prepared to do his part in efficiently distributing sustaining foods to those overseas who need or seek them. May we expand upon our cooperative efforts.

New Developments in Meat Products[a]

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(A REVIEW)

By use of improved methods of processing, the meat packing industry has recently developed meat food shortenings which are excelled by no other shortenings. The development of effective antioxidants, that not only retard the onset of rancidity in the shortening but also retard rancidity in the foods made with the shortenings, has made it possible to produce meat food shortenings with stabilities comparable to those of the best hydrogenated vegetable shortenings. The meat fats are refined and deodorized to remove free fatty acids and to produce a bland and odorless fat. Harder fats are blended with softer fats or small amounts of hydrogenated fats are added to to obtain a suitable consistency of the shortening. A small amount of an antioxidant is added to give the product high stability. The emulsifying properties of the fat may be increased by addition of mono- and diglycerides. With added emulsifiers the shortenings give excellent performance in cakes. The shortening is then chilled, plasticized and packaged in attractive metal cans. It is not necessary for the housewife to store these shortenings in the refrigerator as is the case with ordinary lard. These new and improved meat food shortenings are meeting with good acceptance by the housewife. Special meat food shortenings are finding increased use for industrial baking and deep fat frying.

Although earlier experiences in marketing frozen meats were not too successful, in the past few years the industry has been marketing successfully frozen hamburgers, sandwich steaks, veal cutlets, liver and similar items. The products are wrapped with a moisture-proof film and frozen rapidly. To obtain best results it is necessary to have the film drawn tightly around the meat to eliminate air spaces as completely as possible. If this is not done, frost formation occurs on the inside of the film. Frost formation promotes freezer burn and

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impairment of the color of the product. Proper holding temperatures are also important in retention of quality. Public acceptance of the products is good, especially of the well known items.

A recent development in packaging of frozen meat items for retail sales is the use of a completely enclosed chip board carton. A full-color illustration, showing the product as it appears cooked on the dining room table replaces the cellophane window which provided the consumer with a view of the product. Consumer tests indicate that the appetite-appeal of the prepared dish fully compensates for the loss of visibility of the product. The closed package protects against light-induced deterioration in the show case, and also withstands much more handling in the display case.

One of the most significant developments in the industry during the last two years is the production of self-service packaged items. In many instances the products are not new but the change to self-service marketing has brought about a change in packaging to smaller units. Both fresh and cured meats as well as frozen meats are packaged as self-service items. Generally the fresh meats are packaged by the retailer, although there are some exceptions.

A recent survey indicates the rapid increase that is taking place in self-service marketing of meat. The number of stores with 100% self-service meats has doubled during the last year. As of April 1, 1951, 3,972 stores had complete self-service departments. Although self-service stores represent less than 2% of all stores handling meat, they sell 10.2% of the meat compared with 6.0% a year ago.

One of the most difficult problems in self-service items is the prevention of discolorations in the product. The problem in fresh meats is different from that in cured meats. With cured meats the package should have low permeability to oxygen and moisture. In the presence of oxygen, the color of cured meat is impaired. Light also promotes the discoloration and fading of cured meats. Vacuum packaging in cellophane laminated with pliofilm has been developed to improve color and quality retention in sliced cured meats. On the other hand, fresh red meats lose their bright color and turn dark if packaged in films of low permeability to oxygen. For packaging fresh red meats the film should be permeable to oxygen but low in moisture permeability.

A new product which has met with very wide consumer acceptance is the 8 or 10 ounces of liver sausage or Braunschweiger packaged in a transparent plastic film. The product is protected from contamination since it is pasteurized after packaging. It has increased storage life under refrigerations, with little or no color, flavor or nutritional deterioration when displayed or stored under refrigeration. The product is packaged economically and easily identified by the manufacturer at a controlled net weight. It is conveniently handled by the retailer and the consumer.

A recent development in a frozen meat item is the fat emulsion-coated veal roll. Fat, gelatine, and water are used as an emulsion in place of the old method of coating the veal roast with caul fat. One of the difficulties experienced in the conventional method of dip coating frozen meat cuts is the tendency of the coating to split and separate from the meat during handling. This is overcome by using the emulsion coating and modifying the dipping procedure. The veal roll is frozen at 0° F. or lower. Then the roll is immersed in a liquid bath at 200° F. for about 5 seconds. Thus a shallow surface layer is thawed which permits a firmer adhesion of the coating on the meat. The frozen roll is then promptly dipped in the fat emulsion held at a temperature of 110° to 112° F. and agitated constantly to prevent separation of the ingredients. The coated rolls are stored frozen.

This treatment results in a more uniform application of the fat and a more pleasing appearance of the veal roll. The emulsion protects the veal against freezer burn during storage. It also protects the roast during the cooking process, resulting in a more juicy finished roast. The coating also serves to protect the product from deterioration while in the hands of the retailer. For small size families the retailer can cut the roll in half without exposing more than the cut end. To make the process practical it was necessary to mechanize the process as much as possible and thus produce the veal roll with low man-hours of labor. The proper temperatures for dipping had to be worked out to secure efficient and uniform coating. The product has found excellent consumer acceptance.

Canned meats suitable for babies and children have been receiving excellent consumer acceptance in recent years. Twenty-five years ago babies were fed almost entirely on milk. Meat was not fed until the child reached the age of one to one and one-half years. One reason why little meat was fed was because it was difficult to prepare properly the meat in the home. Physicians generally hesitated to recommend pork or veal for babies. In cooperation with pediatricians and other medical scientists, the industry found that the prejudice against pork and veal was not based on fact and that meat, if properly prepared, could be fed to babies. A finely-chopped product is canned for small babies and a coarsely-chopped product for young children. A variety of products are prepared including pork, veal, lamb, beef, heart, liver, and liver and bacon. A milk substitute for use with babies allergic to milk also has been developed recently. It consists of strained meat, fat, carbohydrates, minerals, and vitamins.

The Meat Food Product Bar was developed recently for use in special rations of the armed forces. It consists of dehydrated meat (50% pork and 50% beef) and oleo stock. It contains about 45% fat and not more than 8% or less than 4% of moisture. The meat is precooked and then dehydrated in vacuum driers. The product is quite acceptable for the conditions under which it is used.

The sole source of many of the raw materials used by the pharmaceutical industry is of animal origin. Recently three new pharmaceutical products have been developed on a commercial scale: ACTH (adrenocorticotropic hormone) and crystalline trypsin by the meat industry, and cortisone by pharmaceutical companies from bile collected by the meat industry. ACTH has been found promising in the treatment of rheumatoid arthritis, gout, lupus erythematosus and pathological conditions involving the secretion of the adrenal gland.

Crystalline trypsin prepared from the pancreas residue of insulin production appears promising in the treatment of empyae, osteomylitis, gangrene, and wounds.

The methods devised during the last war for the separation of protein fractions from human plasma have been applied by the meat industry to cattle blood. Fibrinogen, fibrin films and foams, gamma, beta and alpha globulin and albumin in relatively pure forms have been prepared. The albumin is used as a diluent in Rh typing, for the culture of pathogenic organisms and as a standard reference protein.

Notes and Letters

Vibrating Screens in Tomato Juice Manufacture

To the Editor of *Food Technology:*

In the August issue of FOOD TECHNOLOGY [5, 314 (1951)], a paper entitled "Measurement and Control of Color in the Canning of Tomato Juice" [by W. B. Robinson, J. R. Ransford and D. B. Hand] seems to contain many statements which are much too broad and which are not qualified by comparison of the equipment used in the tests for the screening of the juice with the equipment most widely used in the industry for tonnage production in the East. I will limit my remarks to the following quotations and number my remarks to conform with the numbers which I have inserted in the text:

". . . Similarly, other factory practices and innovations may be evaluated from the color standpoint. Some plants use a vibrating screen in the tomato juice line immediately before the finisher. (1) Theoretically, the screen is supposed to eliminate such defects as hard green spots and yellow shoulders. The waste from (2) such a screen in the Geneva pilot plant was collected and extracted in the laboratory Seprosiv. A comparison of the color of the juice from such an extraction and that of the juice from the pilot plant finisher shows that the use of the screen was actually deleterious to color during the greater part of the season."

"Since the waste from the screen is made up largely of skin and attached flesh (3), the screen will remove relatively more color when the internal parts of the tomato are not as well colored. On the other hand, in extremely hot seasons when the tomatoes are subject to higher incidence of sun-scald, it is possible that the screen might be of value. (4) It should be kept in mind that the screen always reduces the yield of canned juice."

Reference (1). We question the use of the word "theoretically." We do not believe that theory need enter a discussion of a method by which materials are being successfully processed in the United States in equipment having a potential capacity of over 700 tons per hour. Vibrating screens are being used in the tomato industry to remove hard spots, stems, cores, scar tissue, cat faces and unripe portions; to lower the mold count through the removal of mold clusters without breakdown and to deliver practically all of the valuable color material with the juice, all this being done without overall reduction of the yield.

Reference (2). The screen used in the Geneva pilot plant was an offset weight unit which does not have a positive eccentric action and operates with a downhill slope. Its action does not duplicate that of other vibrating screens as for instance of the Selectro Screen which has a positive eccentric action in which every portion of the screen deck has a true circle motion in a vertical plane and which is always used in an uphill slope in tomatot processing so that the waste material is removed from the juice and moved upward over the screen surface with a distinct drying action.

Reference (3). The waste from the overs from the screen in the Geneva pilot plant no doubt did consist largely of skin and attached flesh but this does not correspond to the waste removed from the tomato juice by other vibrating screens. The waste from Selectro Screens, for instance, is made up of hard spots, mold clots and fibre clusters and, in repeated tests in commercial production, the juice pressed from this waste has been proven to be off-color and of inferior quality.

Reference (4). We do not know how the authors can substantiate their general statement that the screen always reduces the yield of canned juice. This would be so if the same amount of trimming was done on tomatoes going to a line including a screen, as is done where the screen is not used. However, one of the real virtues of the screen is the elimination of a large portion of the trimming and the juice manufacturers using screens have satisfied themselves that screening is a more efficient way to remove most waste material than is trimming. As you no doubt know, Government figures call for an average of 100 dozen No. 2 cans per ton of tomatoes, which is a yield of around 71.6%. Average figures from our tests show that a break temperature of 184° F. will give 103 dozen No. 2 cans per ton while a break temperature of 192° F. will give 114 dozen No. 2 cans per ton. In the State of New York, over 45% of the plants canning tomato juice use Selectro Screens in their lines. These screens are operating successfully but, of course, they are operating under conditions which have been determined by tests made with tons of material rather than hundreds of pounds. Eastern tomatoes are subject to defects not found in the western fruit and the operating conditions where screens are used should be as follows:

1. Trimming. Only soft, undesirable material should be removed on the trimming line. Average operations indicate that two man hours per ton of tomato feed is all that is necessary.
2. Chopping. Chopping should be very rough, with only enough work done to break open the seed sacks. Excessive chopping, such as is obtained through the use of disintegrators, breaks down the mold clusters and reduces the size of the hard lumps to a point where they will go through the screen.
3. The tomatoes should be subject to a hot break temperature of at least 184° F. One manufacturer of a very high grade juice breaks at 210° F.
4. The material should be screened through a relatively large mesh wire, commercial installations running from 2½ to 5 mesh. Mesh should be selected to retain the hard spots, stems and so on while, at the same time, all of the good flesh and a very large portion of the skin will pass through the screen.
5. The screen should be of a type which can be operated at an uphill slope, the liquid feed being at the lower end and the dejuiced refuse being delivered off the upper end. The waste should be so dry that juice will not run from a pile if discharged directly onto the floor.

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August 22, 1951.

Book Review

ADVANCES IN PROTEIN CHEMISTRY, Vol. VI. Edited by M. L. Anson, J .T. Edsall, and K. Bailey. 453 pages, with Cumulative Subject Index for Vols. I-V. Academic Press Inc., New York, 1951. Price $9.50.

Of the eight articles that comprise this volume, five deal with the physical or organic chemistry of proteins and related compounds, two with metabolic or functional aspects, and one with a specific group of food proteins, viz. egg proteins.

It may surprise those who casually or carelessly think of "dried egg white" as synonymous with egg protein, to know that the latter consists of ovalbumin, conalbumin (an iron-binding protein), ovomucoid (an antitrypsin), lysozyme (globulin G_1), globulins G_2 and G_3, ovomucin, avidin (the biotin-binding protein), and vitellin and vitellenin (and possibly other phosphoproteins of yolk which exist in lipoprotein combination). Dr. Harry L. Fevold, formerly of the Quartermaster Food and Container Institute for the Armed Forces has written an extensive survey of our present knowledge of the composition, solubility characteristics, electrophoretic patterns and other physical properties of egg proteins. Food technologists will recall the review by Drs. Lightbody and Fevold on the storage of dried whole eggs which appeared in Vol. I of Advances in Food Research, Academic Press, 1948. It is interesting to note that he regards the homogeneity of even the best available isolated egg proteins as not yet fully established by current criteria.

Investigators concerned with the more fundamental solutions to the mysteries of proteins will find special interest in Wyckoff's authoritative and beautifully illustrated article on electron microscopy and in Doty and Edsall's paper on light scattering as a means of studying the size, weight and activity coefficients of protein molecules in solution.

The synthetic approach to the chemistry and physical behavior of proteins is covered in a review by Ephraim Katchalski of the Weitzmann Institute of Science in Israel. The synthesis of poly-α-amino acids and the action on them of the principal digestive enzymes are discussed. Roche and Michel contribute an exhaustive article on naturally occurring and artificially iodinated proteins so intimately concerned with the metabolism of the thyroid.

The controversial topic of glutamic acid metabolism in relation to cerebral function is presented from a quite objective and fundamental standpoint in the review by one of the leading workers in this field, Heinrich Waelsch.

Bjorksten has supplied a brief summary of cross linkage reactions of proteins in diverse industrial processes followed by a tabulated index of the pertinent patents.

The articles are uniformly well documented and the volume concludes with not only the usual author and subject indexes but *(mirabile dictu)* with a cumulative subject index covering Volumes I-V of the series. On the whole this volume is of rather limited interest to the practical food technologist but will be invaluable to research workers in the basic problems of protein structure and function.

BERNARD L. OSER.

ADVANCES IN ENZYMOLOGY AND RELATED SUBJECTS IN BIOCHEMISTRY, Vol. XI. Edited by F. F. Nord. 471 pages. Interscience Publishers, Inc., New York, N. Y. 1951. Price $9.00.

This latest volume in the well known series contains the following nine topics:

The Nature of Entropy and Its Role in Biochemical Processes, by Herbert Gutfreund,

Reactions at Interfaces in Relation to Biological Problems, by J. F. Danielli and J. T. Davies,

Chlorophyll Fluorescence and Photosynthesis, by E. C. Wassink,

Thiol Groups of Biological Importance, by E. S. Guzman Barron,

Pectic Enzymes, by Hans Lineweaver and Eugene F. Jansen,

Enzymic Synthesis of Polysaccharides: A Biological Type of Polymerization, by Edward J. Hehre,

The Biological Transformations of Starch, by Stanley Peat,

Chemical Investigations on Alliin, the Specific Principle of Garlic, by Arthur Stoll and Ewald Seebeck,

Some Problems of Pathological Wilting in Plants, by Ernst Gäumann.

As can be surmised from these titles, the topics will have varying appeal to food technologists. The first one, on entropy, is almost pure physical chemistry, and hence might not be appreciated by the brethren, with all due respect to their acumen in other matters. There is considerable of interest to them, however, in the sections on thiol groups, pectic enzymes and alliin, provided the food man wants to dig into the background fundamentals in the plant and animal materials with which he deals. If he wants to dig still deeper to the physiological processes which give rise to the constituents of the tissues, he will find a wealth of up-to-date material in the sections on chlorophyll fluorescence, the transformations of starch and the enzymic synthesis of starch. Although allusion to the practical phases of various topics is made here and there, the idea of the volume, as of its predecessors, is to gather together the most recent information and interpretation on strictly fundamental topics.

There is an extensive bibliography in each section, from 39 to 324 citations. There is an author index and an excellent subject index. This volume also carries indexes to the previous 10 volumes. The paper is good, the printing and figures are good and the binding attractive. Altogether, a welcome addition to the review books.

J. J. WILLAMAN.